NCO 2008:5

Learning from accidents

An anthology based on thoughts and ideas from young research fellows

RÄDDNINGS VERKET

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Swedish Rescue Services Agency

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Contents

Foreword

It is an obvious fact that human development, including the capability to master dangers to our lives, environment and artefacts, in a true sense can be regarded as an ongoing journey of learning from experience. This would lead the novice to assume that the noble art of such learning is a mature and well-defined discipline, to which there is little to add or improve. But there is a lot.

A basic task for us at the Swedish Centre for Learning from Incidents and Accidents (NCO), a section within the Swedish Rescue Services Agency, is to merge accident data from different sectors into holistic pictures of both individual incidents and accidents as well as of the aggregated whole. The increased complexity and connectedness of society on all levels, indeed makes it a good idea to collate and disseminate what is recorded, reported, investigated and analysed in terms of accidents and incidents.

But without a set of how and why questions such an effort might be more or less in vain. So we then went from the static and instrumental Lessons Learned to the dynamic and process-oriented Learning. What to learn, but also how and why. Facts and processes.

When we discussed how best to start the journey of gaining a better and multi-faceted understanding of the concept of Learning from accidents, the idea to do so in the form of an anthology came naturally. Here, the innovative step emerged. By inviting young rather than old scientists, we hoped to catch emerging rather than established thinking. By mixing young scientists from different countries and of both sexes, we hoped to catch truly different views on the topic. This is not to diminish the value of well established networks, but there is an extra thrill in creating new ones.

The process and the results are presented in this book.

It is not my task to comment on the individual papers, but I can assure that my expectations of originality, quality and freshness are more than fulfilled.

It is my task and pleasure, however, to congratulate the young scientists for their excellent papers and to thank the senior scholars for their mentorship and support. And, of course, to endorse the project leader, Johanna, who by her continuous enthusiasm, efforts and networking skills transferred this anthology from idea to reality.

Thomas Gell
Head, Swedish Centre for Learning from Incidents and Accidents

Johanna Runarson

Biography

Role in the Project

Coordinator and editor

Work/Studies today

I work as the Secretary General for the Swedish Development Council for Geographic Information, ULI, a non commercial interdisciplinary national organization that represents the Swedish Geographic Information (GI) community.

Background

I was born in 1978 in the province Gästrikland, Sweden and have an undergraduate degree in urban planning engineering. Earlier working-experience includes a position as project manager and executive officer in the field of GIS, involved in different projects within the field of learning from accidents, at the National Centre for learning from Accidents (NCO), Swedish Rescue Services Agency, Sweden (SRSA).

I gladly spend time on outdoor activities in my beautiful country, on travelling and getting to know new people and on enjoying beautiful art in different forms.

Contribution to this project

I have been in charge of the operational execution of this anthology project, activities and coordination, and have tried my best to monitor, stimulate and assist the members of the project. I have a deep commitment within the field of learning from accidents and think this project represents an excellent way to stimulate young research fellows to contribute to an ever better learning from the past.

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The Project Process

The Anthology on Learning from Accidents has been designed to offer a wide range of insights and viewpoints. It has been compiled by a group of young talented research fellows and supported by three professors active in the field. It is more than just a reference work; it also provides fascinating perspectives in a field where experience is the most valuable asset. By learning from the past we aspire to improve the future.

Need to know

There is a proverb that says, "Best is to know and know that you know. Next best is to know that you don't know. Third best is knowing but not realizing it. Worst is not knowing that you don't know". This certainly pertains to learning from accidents. The best people know what they need to know, and use their knowledge with confidence. When they miss a key piece of knowledge they realize their need to know – and know where to find the missing piece of knowledge. Given the complexity of the world today, any of us could find ourselves in a position with an urgent need to know something at any moment. Experienced or not, the feeling of an eager need to learn together was the driving force for this project.

The gathering

From our networks around Europe, seven young research fellows active in the field of learning from accidents were identified. Three Swedish professors also joined the project and the process got under way. To achieve a common aim and to create an ambitious atmosphere for the project, all of the members were asked to provide a short personal presentation and an account of the intentions of their research, along with a photo which was distributed among the group.

Improvement

The first contribution for the anthology was a draft chapter from each researcher. The material was distributed to everybody for comment. The members of the project then attended a seminar in Sweden in August 2006. The two-day seminar was organised in a process called "Reflecting team". Instead of the classic presentation process followed by questions and criti-

que, an oral presentation from each contributor was followed by a number of steps aimed at getting the most out of the group.
The following steps were set up to achieve a "Reflection Team"

1. One writer (the presenter) gives an oral presentation of his/her contribution.
2. A clarifying phase during which only questions aimed at clarifying the presentation in question were allowed.
3. The reflection phase. The group of writers, except the presenter and the supporting professors, organized themselves in a circle and discussed the given presentation within the group. Everybody was given time to reflect individually without interruption. The presenter is not allowed to be questioned or to comment on anything during this process.
4. The presenter is brought into the circle and is allowed to comment on the discussion taking place. The rest of the participants are not allowed to speak during this phase.
5. The last step provides the group with the option to ask questions and comment on things together, both the presenter and the writers
6. The professors are allowed to give their comments during the final stage of the process when the group feels ready.

The idea behind this process is to allow thoughts to be exposed without being discouraged or interrupted. The process was repeated for each writer. Everybody was given the time and opportunity needed for their comments and the presenter could to take in the reactions without the pressure to defend the work. This fascinating process often results in a feeling of common understanding and the writer is free to use the comments for improving the content of their chapter. All writers gave their presentation followed by this process.

Each day of the seminar started with a morning walk prior to the first session, during which the participants walked in pairs. On one of the mornings the writers walked with a professor. The walk lasted for half an hour and aimed to get the participants together and also give them time to individually comment on each others work. The two-day seminar was held on the Swedish west coast. The calm environment was selected to provide the right conditions for focus and creativity. The seminar included activities at sea and other stimulating activities for the senses of smell and taste

Conclusion

The seminar established a feeling of friendship and result orientation for the project. The participants then went back to their home countries to finalise their individual chapters. There was a final round-robin comments process via email and by the spring of 2007 the anthology had been compiled.

The Anthology provides unique access to new thoughts established through ambitious work. We had a great time compiling this anthology and came to cherish each other and the contribution each person made. We hope that readers will enjoy our final product.

Ana Lisa Vetere Arellano

Biography

Role in the Project

Writer

Work/Studies today

I work as a scientific officer at the Institute for Energy of the European Commission Directorate General Joint Research Centre (EC-JRC-IE).

Background

I was born in 1970 in Manila, Philippines, and have an Italian Laurea in Geology (master-equivalent). I have worked in the European Commission since January 2001. Since December 2004 I work in Petten, The Netherlands where I contribute to the Energy Systems Evaluation Unit. I am part of the institutional project entitled ESSEC (Energy Security and Safety of Energy Chains), which focuses on creating a knowledge base for benchmarking and prioritising risks to the energy supply, assessing their impacts and suggesting mitigation approaches.

Hobbies: Reading, Travelling, Cooking, Wine Tasting, Sports (Trekking, Football, Tennis, Squash, Table Tennis)

I am fascinated by: Interfaces, Intersections & Nodes, in particular those between science/technology/society/environment; Spatial and Temporal Interconnectedness; History, multi-disciplinarity.

I am interested by: Natural and Technological Risks, Energy Risks, Sustainable Development, New Technologies and their impacts, EU Policies; EU & International Institutions and their activities, World Affairs.

I would like to increase my knowledge in: Energy-related issues (life and fuel cycles of all energy sources, markets, geopolitics, inter-related risks, regulations), Risk Perception & Communication, Organisational learning.

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A heuristic odyssey towards good risk governance

> *When setting out upon your way to Ithaca, wish always that your journey be long, full of adventure, full of lore … that many there be of summer morns when with such pleasure, such great joy, you enter ports now for the first time seen … that you may go to various … towns … to learn, and learn from those schooled there … But do not rush your journey in a any way. Better that it should last for many years … (Kavafis, 1911)*

Abstract

Since the dawn of mankind, people have strived to learn from accidents and find better ways of managing them. Throughout the years, society, technology and our environment (socio-tech-env domain) interact and co-evolve, triggering also change in the types of accidents we have to deal with. This paper attempts to depict my personal odyssey in this dynamic and complex landscape. It describes my present mental model and attempts to provide some ideas on how to improve risk governance. Its purpose is also to captivate readers' interest in this field of research and to trigger discussion with those who may wish to share experiences, raise awareness of this fascinating landscape and identify synergies for joint adventures in this domain.

1. Introduction

When I was asked to provide a contribution to this anthology addressing an issue of individual choice, but in line with the theme ***"learning from accidents",*** a lot of questions were triggered in my mind. However, two questions took centre-stage and fuelled my curiosity: **why** do we want to learn from accidents and **how**?

In my opinion, the answer to the former is to improve ***risk governance,*** i.e. we try to learn from accidents in order to assist us in better managing future potential accidents, taking stock of the dynamic and complex world in which we live. Answering the latter, i.e. ***how***, was the challenge I chose take upon myself in this anthology contribution. Hence, this paper describes my quest to better understand concepts and processes related to three chosen and interlinked concepts: ***accidents, learning*** and ***governance*** and to tentatively provide some ideas on how to achieve this. It attempts to describe a dynamic landscape, with the hope that it may act as a trigger for future discussions with other interested parties who may wish to share experiences and identify synergies for joint adventures in this domain, and that I may continue my personal learning process in this fascinating arena. I hope that at the end of this journey, the various processes described will also captivate you and entice you to visit to this realm.

Before embarking on this personal journey with you, I would like to describe the chosen landscape of this contribution, along with its pseudo-boundaries. Section 2 has been dedicated to address this issue, along with the introduction of various concepts I have been attracted to for some reason or other, which perhaps, may, at first glance seem like an unfamiliar landscape to you, but hopefully, towards the end of this essay, you will be more acquainted with it and the various interacting processes within it. Section 3 portrays a selection of ensuing complex processes that may be encountered in this landscape, while Section 4 provides a summary of the key messages of this paper as closing remarks.

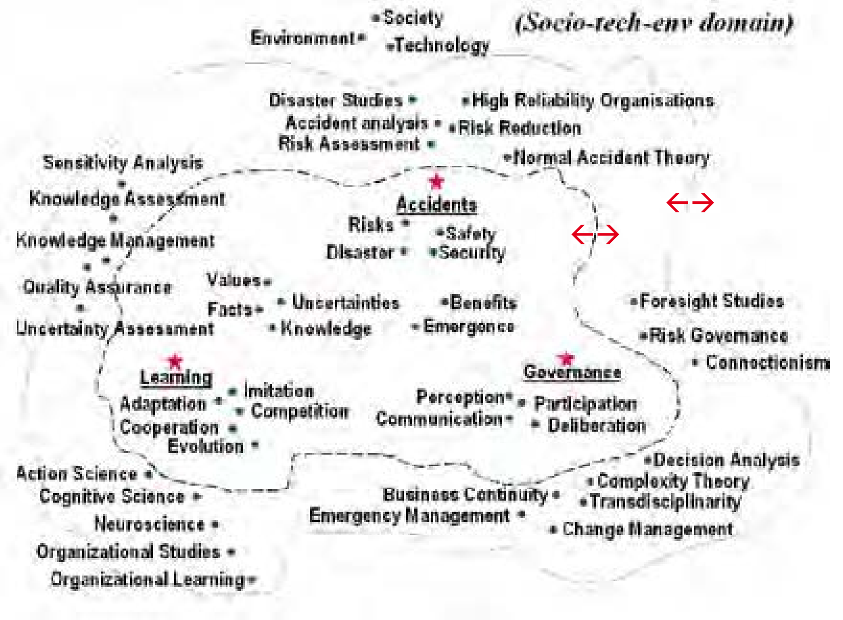

Figure 1 – The chosen landscape of the paper in the Socio-tech-env domain. The red arrows (←→) imply that this landscape is dynamic and is destined to change in time, based on the state of knowledge and understanding.

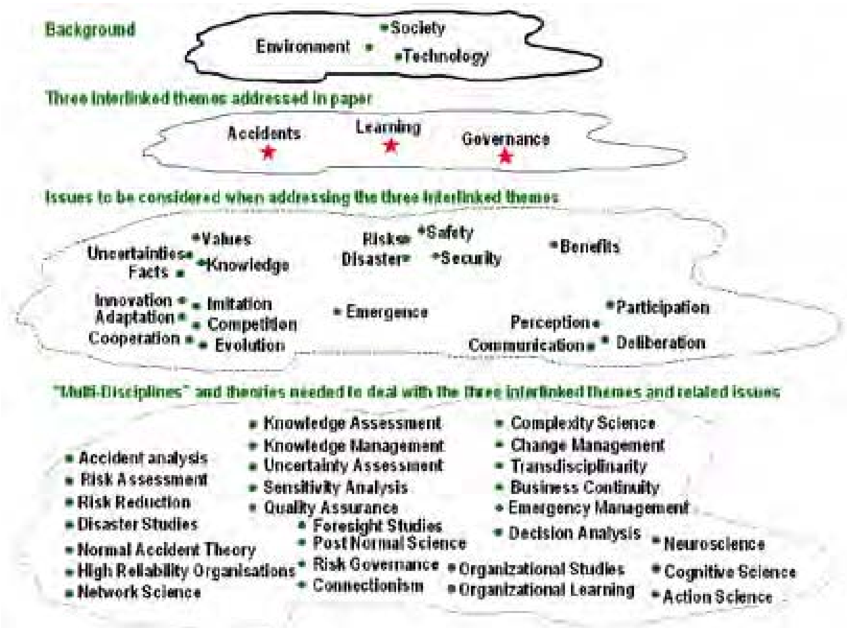

Figure 2 – The chosen landscape described from another perspective: background, themes, issues, disciplines and theories.

2. The landscape

The themes addressed in this anthology contribution can be summarised by using three keywords: *accidents, learning* and *governance*. In my mental model (see Figures 1 and 2 below and Sub-section 2.1 for a more detailed description of its components), the background where these themes interact is at the frontier of three co-existing and co-evolving complex entities: society, technology and environment (*socio-tech-env*).

These three entities are continuously cooperating and competing, resulting in a dance of co-adaptation and co-learning, which have ripple effects at all *levels* and all *sectors* in society.

Levels can be conceptualised in various ways: from an administrative standpoint [local, regional, global]; from a proactive risk management standpoint [individual, staff, management, company, regulatory, government] (Rasmussen, 1994; Rasmussen & Svedung, 2000); from the "Great Chain of Being Theory"[1]angle; or other.

Like the levels described above, *sectors* can also be conceptualised in various ways: public vs. private; different industries/technologies [energy, environment, transportation, etc.]; research vs. commercial; etc.

The *socio-tech-env domain* came to be since man started roaming the Earth. Expressions of this co-adaptation and co-learning dance can be observed in Table 1 below, which is an attempt to provide the reader a quick glimpse of society and technology in European history[2]. We have shifted from a hunter-gatherer lifestyle with simple stone tools to more complex and interconnected interactions in society with sophisticated technologies[3].

1) According to this theory (also known as scala natura), everything in the universe is part of a hierarchical continuum of levels of existence, with components having the lowest ranking at the bottom and those with the highest ranking at the top. This concept originated from ideas belonging to Plato and Aristotle, but were more popularised by the writings of Leibnitz (1686;1714), Spinoza (1677) and Descartes (1637).

2) The table is indeed reductionist in approach, but its aim is to try to communicate the increased complexity in society (reflecting a dance of evolution and learning) and the tools/technology that result from society's changes through time. I do not intend to capture all the details of European History with this table.

3) However, with this table my intention is not to imply that we are smarter now than we were then; each society at a given point in time has a past, with its related societal perceptions of that past, along with perceptions of its related future. As a consequence each society, within its related context had a relative coping capacity related to the socio-tech-env rhythm at that point in time.

Age[5]	Characteristics in society	Characteristic technologies
Pre-historic		
Stone age (ca. 2 million years ago-3,500 BC)	Hunter-gatherer lifestyle: limited use of tools, rock paintings and pre-historic art, prehistoric music	fire, stone tools and weapons, and clothing
Bronze Age (ca. 2,100 BC-450 BC)	Adoption of permanent settlements, trade network, development of live-stock ranches in lowlands (Britain)	agriculture, animal domestication, metallurgical (copper & bronze), navigation
Iron Age (ca. 1,000 BC-500 BC)	Permanent fortified settlements, early towns, extensive trade networks,	iron forging, tools and weapons, ela-borate jewellery, chariots (Hallstatt)
Ancient		
Greece (c.a. 1100 BC-146 BC)	Small city-states (polis), stable for ca. 1000 yrs, 250 years of expansion and colonisation, growth of com-merce and manufacture, appearance of democratic society	basic steam engine, early mechanic and pneumatic systems, ballistae, primitive analogue computers (Anti-kythera mechanism), early piston pump
Rome (c.a. 509 BC-476 AD)	Strengthening of urban areas, more centralised authority, efficient orga-nisation of empire,	intensive and sophisticated agri-culture, advanced stone masonry technology, concrete, advanced road-building, military engineering, civil engineering, spinning and weaving

Table 1[4]- A glimpse of European society and technology throughout history.

4) However, with this table my intention is not to imply that we are smarter now than we were then; each society at a given point in time has a past, with its related societal perceptions of that past, along with perceptions of its related future. As a consequence each society, within its related context had a relative coping capacity related to the socio-tech-env rhythm at that point in time.

5) Put together with information from Wikipedia (retrieved 19 February 2007 from http://en.wikipedia.org) and complemented by valuable comments from my work colleagues much more knowledgeable than me in history. The dates below the ages in parenthesis are indicative, as one cannot really identify an exact year when a particular age starts and ends and also some ages started first in certain parts of Europe and then gradually affected the other parts.

Age	**Characteristics in society**	**Characteristic technologies**
Middle Ages[6] (ca. 5th-15th Century)	Feudal system, general collapse in trade, manufacture, also administrative, educational and military infrastructure diminished, leading to decreased literacy and reduced governmental sophistication, crusades, first appearance of city-states (Late Medieval), teaching of liberal arts[7]; however, in some parts of Europe, e.g. Spain, the Moors influx brought some innovations to Medieval society from outside Europe.	artesian wells, cannons, compass, silk, soap Imported from outside Europe: anatomy early brain surgery, irrigation technology, crucible steel technology[8]
Early Modern		
Renaissance (ca. 15th-16th Century)	Re-connection with classical antiquity, absorption of knowledge (particularly mathematics), humanism, explosion of dissemination of knowledge, start of exploration, Reformation, trade, industry, and banking, competitive overproduction, heightened competition to maximize economic advantage, aggressive militarism, centralisation of power, start of scientific revolution (16th Century)	Printing and moveable type, new techniques in art, poetry, and architecture, diffusion of gunpowder technology, textiles, armaments, mining of iron ore, telescope, windmills and irrigation system (wind energy used to pump water [The Netherlands]). Also when Leonardo da Vinci anticipated recent technological achievements: plane, helicopter, submarine etc.

Table 1 (cont.)

6) The Middle (or Medieval) Ages are generally subdivided into three parts: Early Middle Ages, High Middle Ages and Late Middle Ages. The Medieval Ages were characterised as Dark Ages, denoting a discontinuity in progress in science and technology in Europe. However, it was not like this everywhere in Europe (e.g. Spain) because thanks to foreigners' influx, they brought knowledge of algebra, numbers and astronomy.

7) Liberal arts are studies that provide general knowledge and intellectual skills. In medieval universities, the curriculum consisted of seven liberal arts, which were taught under two groupings: trivium (grammar, dialectic [logic], and rhetoric) and quadrivium (arithmetic, music, geometry, and astronomy).

8) Production of steel by gradual heating and cooling pure iron and charcoal in a crucible.

9) Production of steel by cementation process to produce blister steel.

10) Mass industrial production of steel by removing impurities from the iron via oxidation of air blown through molten iron (Bessemer process of 1850s).

11) A "citizens' compendium of everything; it is an experimental new wiki project that aims to improve on the Wikipedia model by adding "gentle expert oversight" and requiring contributors to use their real names. Retrieved 19 February 2007 from http://www.citizendium.org.

Age	**Characteristics in society**	**Characteristic technologies**
Enlightenment (ca. 17th-18th Century)	Advocated reason to establish an authoritative system of aesthetics, ethics, government, and logic to obtain objective truth about the universe, Newtonian kinematics and its application to all forms of human activity, baroque music	birth of central banking, modern finance, calculus, binary system, 1st newspaper, barometer, submarine, microscope, 1st steam engine (energy production using chemical reactions [burning]), improved steel technology[9]
Modern		
Industrial Age (ca. 18th-19th Century)	Nation-states, end to caution in allowing radical ideas to be made public, initiation of mass literacy, early mass media, new attitudes towards religion, with the church diminished, and a desire for personal freedoms, professionalisation and institutionalisation of science	steam engine (drove development in textile manufacturing, metallurgy, transport sectors); developments in the chemical, petroleum, steel and electrical industries, telephone, telegraphy, radio, automobile, start of research on atomic power, modern steel technology[10]
Information Age (ca. 20th Century)	Birth of Megacities (Megalopolis), period when information was conceived as a rarity (importance on quantity) and its obtainment and management led to competitive advantage, digital age, focus on education, globalisation, sustainable development, world trade agreements, international and regional organisations, environmental movements, disaster response, birth of "multi-disciplines"	Computer, television, airplane, photography, o-ring, nuclear technology, mobile telephony, holography, laser, microtechnology, internet, database, network infrastructures (energy, transport, communications, telecommunications)
Knowledge Economy (ca. 20th-21st Century)	Proliferation of megacities, Information seized to be scarce (importance on quality), economy-driven society, networking society, risk society, management of risks and vulnerabilities, disaster preparedness and mitigation, increased awareness on importance of interdisciplinarity, proliferation of multidisciplines	Nanotechnology, biotechnologies, knowledge base, environmental technologies, hydrogen technologies, aerospace technologies, web technologies (google, wikipedia, myspace, youtube, etc.), Genetically Modified Organisms
Intangible Economy (21st Century)	Management of uncertainties, "terrorism-aware" societies, .. ???	Bio-nano-info technologies, citizendum[11], life extension, genetic human modifications, .. ???

How is this table related to *accidents, learning* and *governance?* Everything. Society has co-evolved with technology and society has learned to cope in some way or other with the related accidents resulting from the evolving socio-technological interactions throughout history. One could imagine the earlier types of accidents that occurred: in *Pre-Historic Times* it could have been a man accidentally getting hurt from fire or from using stone tools; in *Ancient Times,* it would not be surprising to imagine agriculture-related accidents to not have been rare; in the *Middle Ages,* accidents could have been expressed by faulty cannons (e.g. cannon balls exploding without ejecting from the canon); in the *Early Modern,* sinking ships during a maritime exploration were probably not scarce back then; in the *Industrial Age,* preventing the failure of telegraph lines must have been a challenge; in the *Information Age,* transportation accidents have become quite frequent; in the *Knowledge Economy* era, "butterfly effect"[12] events are becoming more and more common, e.g. the autumn 2005 hurricanes Katrina and Rita that devastated the petroleum refineries on the Gulf Coast, triggering a shortage in supply, leading to higher oil prices. These type of events will probably differentiate and proliferate into other sub-typologies in the *Intangible Economy* era. Who knows in what form and how?

2.1 Heuristic Odyssey

Figures 1-2 above are an attempt to show a few snapshots of the above-mentioned dynamic landscape, expressed as mental models that I would like to share with you. I admit from the start that they are "reductionistic" per se, as they do not capture the actions and interactions in this landscape; however they are a means to an end. I would like to use them to communicate the various concepts I feel are important in this area of ***"learning from accidents".*** Please note that this landscape is based on my present "baggage" of knowledge, which in turn is derived from my past (natural and technological risks and civil protection) and present (energy risks, safety and security) work experiences. I hope that through these mental models, I will be able to convey the various processes that are taking place with regards to **learning from** and **dealing with *accidents.***

In this Sub-section, Figures 1 and 2 will be described in more detail. In Figure 1, the above-mentioned *socio-tech-env domain* consists of an inner

12) Used to describe the phenomenon of being "sensitive to initial conditions", with theexample of a butterfly flapping its wings in Peking can trigger storm systems in new York the following month (Gleick, 1987).

landscape and an outer landscape. The inner landscape (area within the darker set of dashed lines), you can observe three capital cities (represented by the stars and are underlined too) *Accidents, Learning* and *Governance.* These are three main principal themes of this paper.

In order to get acquainted with this landscape, I will to try act as your guide by providing you with two selected definitions for each of these three words:

- **Accident:** that occurrence in a sequence of events, which usually produces unintended injury, death or property damage (SRA, 2003); unintended damaging event, industrial mishap (NOAA, 2006).
- **Learning:** can be grouped into two: *exploitation learning:* improving what you already have and *exploration learning:* taking the risk of messing up big in return for the chance of winning big [in the context of Connectionism Theory] (Waldrop, 1992); an increase in the capability for effective action. Individual, team, and organizational learning can all be measured by the outcomes that result from effective action. This definition emphasizes the importance of taking actions and achieving results vice intellectual knowledge without application (Mountain Quest Institute, 2005).
- **Governance:** it means rules, processes and behaviour that affect the way in which powers are exercised … , particularly as regards openness, participation, accountability, effectiveness and coherence (European Commission, 2001); at the national level, the structure and processes for collective decision making involving governmental and non-governmental actors [Nye and Donahue 2000]. At the global level, governance embodies a horizontally organised structure of functional self-regulation encompassing state and non-state actors bringing about collectively binding decision without superior authority (Rosenau, 1992; Wolf, 2002; IRGC, 2006).

Around these three capitals, you will notice a clustering of towns, which are keywords[13] that come to my mind when I think of them. In the paragraphs below, I will provide some selected definitions to the various keywords, which will be followed by a brief explanation (framed in a box) of their linkage to the main theme around which they are clustered. I apologise in advance for this list of definitions in following pages (8-23). However,

13) Every keyword found in the inner landscape has many definitions from a plethora of sources. I have selected two for each of them.

they are necessary for you to better understand the related interlinking concepts that are an integral part of this landscape.

2.1.1 Towns related to Accidents

Near *Accidents* there are four towns:

- **Risks:** combination of the frequency or probability of occurrence and the consequence of a specified hazardous event (IEC, 1995); probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (UNISDR, 2004).
- **Disasters:** state in which the social fabric is disrupted and become dysfunctional to a greater or lesser extent (Fritz, 1961); serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources (UNISDR, 2004).
- **Safety:** freedom from unacceptable risk (ISO/IEC, 1999); relative protection from adverse consequences (SRA, 2003).

It is difficult not to relate the *word* risk to the word *accident*. An accident is a *realised risk*. Achieving *safety* implies carrying out what can be done to prevent a given accident from occurring, and/or to minimise an accident's impact, if it were to occur. *Security* on the other hand *"is an evolving concept and presents many challenges to the EU-25*[15] *that impact on a wide range of existing and emerging EU policies, citizens' concerns, including the protection against terrorist threats, and the adaptation of governance structures to effectively deal with these matters"* (European Commission, 2004). Although in most European languages *safety* and *security* are expressed with the same word[16], organisations and institutions in society generally reflect the French and English splitting between the two concepts: *safety* tends to be linked with civilian activities, whilst *security* tends to be the mandate of the military.

14) In the energy sector, security also connotes all actions and processes ensuring the availability of supply.

15) Abbreviation used for the European Union (EU) consisting of 25 Member States (since 1 May 2004). On 1 January 2007, Bulgaria and Romania joined the EU to become EU-27.

16) Sicherheit (German), sicurezza (Italian), säkerhet (Swedish), seguridad (Spanish), segurança (Portuguese), sikkerhed (Danish), zekerheid (Dutch); however, in French safety (sécurité) and security (sûreté) are different entities.

- **Security**[14](human): refers to monitoring and reducing the risk of human induced events that adversely affect people or property (intrusion of unauthorized personnel, theft, sabotage, assault, etc.), to some acceptable level (NOAA, 2006); to protect the vital core of all human lives in ways that enhance human freedoms and human fulfilment. Human security means protecting fundamental freedoms that are the essence of life. It means protecting people from critical (severe) and pervasive (widespread) threats and situations (Commission on Human Security, 2003).

2.1.2 Towns related to *Learning*

Near *Learning* there are a cluster of six towns:

- **Evolution:** any process of gradual change occurring in something, esp. from a simpler to a more complicated or advanced state (Shorter Oxford English Dictionary, 2002a); a process of change in a certain direction (Merriam-Webster Online Dictionary, 2007).
- **Adaptation:** process by which an organization improves its ability to survive and grow through internal adjustments … (it) may be responsive, internally adjusting to external forces, or it may be proactive, internally changing so that it can influence the external environment (Mountain Quest Institute, 2005); act or process of bringing one thing into correspondence with another; modification according to

Learning is an *evolutionary* process occurring in time as information and experiences are collected (active) and assimilated (passive). *Learning* can take place by *adapting* to change, *cooperating* with others, *competing* with others and *imitating* others. These interacting processes lead to *innovation.*

According to Argyris (1991): *most people define learning too narrowly as mere "problem solving", so they focus on identifying and correcting errors in the external environment. Solving problems is important. But if learning is to persist... (people) need to reflect critically on their own behaviour, identify the ways they often inadvertently contribute to the organization's problem, and then change how they act.* It therefore is essential that *double-loop learning*[17] be promoted in addition to *single-loop learning*. Furthermore, whilst we are evolving, it is essential that we strive towards the convergence of our *espoused theories* and *theories-in-use.*

17) Argyris (1991; 1994) coined the terms single-loop and double-loop learning by using the thermostrat analogy. Single-loop learning: a thermostat that automatically turns on the heat whenever the temperature in the room drops below a given threshold (1991); it asks a one-dimensional question to elicit a one-dimensional answer (1994). Double-loop learning: when the thermostat is able to ask "Why am I set at this temperature?", and then is able to explore whether or not some other temperature might more economially achieve the goal of heating the room (1991); it takes an additional step, or more often than not, several additonal steps and asks questios not only about objective facts but also about the reasons and motives behong those facts (1994).

changing circumstances (Merriam-Webster Online Dictionary, 2007).
- **Cooperation:** action to act or work with another or others; associating with another or others for mutual benefit (Merriam-Webster Online Dictionary, 2007).
- **Competition:** the act or process of striving consciously or unconsciously for an objective (as position, profit, or a prize); being in a state of rivalry (Merriam-Webster Online Dictionary, 2007).
- **Imitation:** action or practice of imitating or copying (Shorter Oxford English Dictionary, 2002a); an act or instance of following as a pattern, model, or example; quality of an object in possessing some of the nature or attributes of a transcendent idea (Merriam-Webster Online Dictionary, 2007).
- **Innovation:** a novel, beneficial change in art or practice (Palo Alto Rehabilitation Research and Development Center, 2007); a new idea, method, or device (Merriam-Webster Online Dictionary, 2007).

2.1.3 Towns related to *Governance*

Near *Governance* there are four towns:
- **Participation:** the action or act of taking part with others (in an action or matter), spec. the active involvement of members of a community or organization in decisions which affect them (Shorter Oxford English Dictionary, 2002b).
- **Deliberation:** the action of deliberating, careful consideration, weighing up with a view to decision; spec. consideration and discussion of a question by a legislative assembly, committee, etc.; debate (Shorter Oxford English Dictionary, 2002a).
- **Communication:** spec. the transmission or exchange of information, news, etc.; the science and practice of transmitting information (Shorter Oxford English Dictionary, 2002a).
- **Perception:** The state of being or process of becoming aware or conscious of a thing, spec. through any of the senses. The intuitive or direct recognition of a moral, aesthetic, or personal quality e.g. the truth of a remark, the beauty of an object. The action of the mind by which it refers its sensations to an external object as their cause (Shorter Oxford English Dictionary, 2002b).

Good governance when dealing with risks and accidents is achieved through democratic processes that promote and implement participation, deliberation and communication amongst the plurality of stakeholders in an accountable, coherent, effective and transparent manner. These processes would improve perceptions enabling a better understanding of accidents and their management.

2.1.4 Towns related to Accidents, Learning and Governance

Finally, there are six towns situated in the middle part of the inner landscape. These six concepts have been placed in this area as they are related to all the other towns in the landscape.

- **Benefits:** advantages (Shorter Oxford English Dictionary, 2002a); something that promotes well-being (Merriam-Webster Online Dictionary, 2007).
- **Emergence:** a global property of a complex system (organization) that results from the interactions and relationships among its agents (people), and between the agents and their environment. These characteristics represent stable patterns of the organization that are qualitative and exert a strong influence back on the individuals and their relationships (Mountain Quest Institute, 2005); the process … takes places at the boundary between the system and its constituents, if the border between local and global, micro and macro, individual and collective behaviour is crossed. It distinguishes between local, low-level components and global, high-level patterns … it emphasizes the bottom-up process, the appearance of new and novel structures at a higher level, but is not possible without a top-down feedback process (Fromm, 2005).
- **Knowledge:** understanding of a branch of learning, a language, etc.; a theoretical or practical understanding of an art, science, industry, etc.; intellectual perception of fact or truth; clear and certain understanding or awareness, esp. as opp. to opinion. Formerly also intelligence, intellect (Shorter Oxford English Dictionary, 2002a).
- **Facts:** truth; reality; a thing known for certain to have occurred or to be true; a datum of experience; a thing assumed or alleged as a basis for inference (Shorter Oxford English Dictionary, 2002a).
- **Uncertainties:** the amount of variation in a numerical result that is consistent with observation; quality or state of being uncertain; a doubtful point. A thing of which the occurrence, outcome, etc. is uncertain (Shorter Oxford English Dictionary, 2002b).

When an *accident* occurs, there are also *benefits* to be reaped, as an *accident* is an opportunity to *learn* and increase our *knowledge* to improve the accident investigation process, accident prevention and mitigation processes and the *risk governance* process, bearing carefully in mind *emergence* processes. In addition, when decisions need to be made in the face of *risks, benefits* and *uncertainties* need to be considered and co-weighed, along with *facts* and *values.*

- **Values:** the worth, usefulness, or importance of a thing; relative merit or status according to the established desirability or utility of a thing. Estimate or opinion of regard or liking for a person or thing. Principles of moral standards of a person or social group; the generally accepted or personally held judgement of what is valuable and important in life. The quality of a thing considered in respect of its ability to serve a specified purpose or cause an effect (Shorter Oxford English Dictionary, 2002b).

This is my personal heuristic odyssey through the towns of this vast landscape. I am aware that there may be other framing scenarios and that they may be interlinked in another manner. However, this selection of towns that cluster around each capital has been my personal choice and my personal framing at this point in time. The next section will look at the various "multi-disciplines" related to accidents, *learning* and *governance.*

2.2 Pandora's box syndrome and "multi-disciplines"

At the start of this journey in this landscape, I had planned to visit the capitals, without knowing exactly what I would encounter along the way. The experience I went through was similar to that of Pandora: each capital, *Accidents, Learning* and *Governance,* brought unanticipated discoveries of other towns that led to other towns. Furthermore, each town offered a plethora of fascinating and interconnected communities that would require more time to visit and learn about.

Moreover, I also discovered the "multi-disciplines", which are situated along the outer rim of the landscape in Figure 1. They are portrayed in another manner in Figure 2. "Multi-disciplines" are disciplines that emerged from the combination of other disciplines. It is out of the scope of this paper to provide a detailed explanation on these "multi-disciplines"; however, it is essential to introduce them, as they provide insight on the various areas interrelated to *accidents, learning* and *governance.* This introduction aims to trigger some thoughts in readers' minds regarding the clustering of the "multi-disciplines" in my chosen landscape; they are not random. In my mental map, I have made an attempt to group them according to the capitals and towns on which they are more likely to provide insight (see Figure 1). It is these "multi-disciplines" that will help us better understand the interacting and co-evolving actors and processes in the *Socio-tech-env* domain. In the paragraphs below, I will briefly introduce the various "multi-disciplines", which will be followed by a brief explanation (framed in a box) of their linkage to the main theme around which they are clustered.

2.2.1 Multi-disciplines related to *Accidents*

Near *Accidents* there are seven "multi-disciplines":

- **Normal Accident Theory[18]:** complex systems that occasionally, the right combination of events (e.g. two or more failures – none of which are devastating, when taken in isolation) could come together in unexpected ways and defeat safety devices and management systems resulting in a catastrophe. In addition, if the system is tightly coupled, these failures can cascade faster than any safety device or operator an cope with them, or they can even be incomprehensible to those responsible for doing the coping (Perrow, 1984); systems with interactive complexity and tight coupling will experience *system accidents,* i.e. interaction of independent and unpredictable failure events, due to tight coupling, which result in the cascading of effects that quickly spiral out of control before operators are able to understand the situation and perform appropriate corrective actions, leading to severe consequences (Marais et al., 2004).
- **High Reliability Organisations (HROs):** subset of hazardous organizations that enjoy a record of high safety over long periods of time (Marais et al, 2004): *one can identify this subset by answering the question, 'how many times could this organization have failed resulting in catastrophic consequences that it did not?' If the answer is on the order of tens of thousands of times, the organization is 'high' reliability* (Roberts, 1990). According to HRO researchers, this is the result of a strong safety culture expressed as, openness to learning from accidents, including near misses (instead of blame-seeking), delegation of responsibility to the levels closest to the technical operation of the components in ques-

18) It was first used by Charles Perrow.

tion, redundancy in personnel handling especially intense and critical tasks, and multiplication of redundant fail-safes (Rodrigue, 2004).

- **Disaster Studies[19]:** socio-economic vulnerability to disasters and disaster management - principally mitigation and preparedness (Benfield Hazard Research Centre, 2006); education, research and policy advice on the issues of conflict and natural disasters, the relations between these crises and processes of development, and the dynamics of aid interventions during and after disaster and conflict. It contributes with qualitative research to multi-disciplinary approaches…and combines academic teaching and research with a desire to enhance policy discussions and local and international responses to disaster and conflict. Research is interactive in nature and builds on dialogue with policy-makers and people in the field (Wageningen University, 2007).
- **Risk Assessment:** The task of identifying and exploring, preferably in quantified terms, the types, intensities and likelihood of the (normally undesired) consequences related to a risk. Risk assessment comprises hazard identification and estimation, exposure and vulnerability assessment and risk estimation (IRGC, 2006).
- **Risk Reduction:** consequence of adjustment policies which intensify efforts to lower the potential for loss from future environmentally extreme events (Mileti, et al., 1981; Nigg & Mileti, 2002); it involves both policy/regulatory issues and planning practices and is the result of what has earlier been defined as risk management related response [prevention orientated mitigation, non-structural mitigation, structural mitigation, and reaction] (ESPON, 2003).
- **Accident Analysis:** analyses of past accident scenarios serve to describe the socio-technical context within which accidental flow of events are conditioned and ultimately take place (Rasmussen & Svedung, 2000); identification of the chain of circumstances that causes an accident (CAIB, 2003).
- **Network Science (or Network Theory):** subject within applied mathematics and physics, and coincides with graph theory. It has application in a varied range of disciplines including computer science, biology, economics, and sociology … (it) concerns itself with the study of graphs as a representation of either symmetric relations or, more generally, of asymmetric relations between discrete objects. Typically, the

19) Barry Turner was one of the forefathers of Disaster Studies. It was not easy to find a definition of disaster studies. I ended up looking for definitions from the curricula of universities and research centres.

In the present day society, infrastructures and networks, such as energy, telecommunications and transport, are complex and very much interconnected. In addition, such networks tend: to be mutually dependent on each other, to go beyond administrative borders and to require cooperation amongst several countries. Many sectors (industrial, agricultural, households, etc.) also depend on such networks to be robust and reliable systems. Against this background, a failure in one system could trigger unaccounted for events in another system, e.g. electricity disruption would have an impact on telecommunications and information technology systems. Thus, Normal Accident Theory would ensure that we do not forget to address complexity and degree of coupling when designing for and managing high-technology systems; *High Reliability Theory* provides a methodology to prevent accidents through organizational design and management; *Disaster Studies* provides an understanding of how a disaster develops, i.e. six stages of disaster development and may provide insight on how to identify precursors (Turner & Pidgeon, 1997); *Risk Assessment* enables us to identify potential hazards and their possible consequences, whilst *Risk Reduction* assists us by acting on reducing the identified risks through policy/regulatory issues; when an accident does occur, then *Accident Analysis* would allow us to identify the root causes of the event and identify weak points in the operational and managerial processes that require strengthening. *Network Science* assists us to better analyse nodes and links that comprise the many networks (transportation, energy, fluvial, cellular, etc.) existing in society.

graphs of concern in network theory are complex networks, examples of which include the World Wide Web, the Internet, gene regulatory networks, metabolic networks, social networks, epistemological networks, etc. (wikipedia, 2007).

2.2.2 Multi-disciplines related to *Learning*

Near *Learning* there are five "multi-disciplines":

- Action Science[20]: attempts to create communities of inquiry within communities of practice by integrating social research into social practice and focuses on building and testing theories of practice in situations characterized by uniqueness, uncertainty, instability, and value conflict. It aims to help practitioners, both individually and collectively, discover the tacit choices they have made about their perceptions of reality, their goals, and their strategies for achieving them.
- **Organisation Learning:** process by which an organization acquires the knowledge necessary to survive and compete in its environment ... (it) includes the development of knowledge and understanding, shared among organizational employees, that leads to effective action. A learning organization is one with the capacity to acquire the knowledge

20) It was pioneered by Chris Argyris and Donald Schön (1974). Retrieved 19 February 2007 from http://www.actionscience.com; http://www.actionscience.org; http://www.actiondesign.com/resources/bibliography/index.htm.

necessary to survive and compete in its environment (Mountain Quest Institute, 2005); when human beings cooperate in dynamical systems that are in a state of continuous adaptation and improvement (Senge, 1990).

- **Organisational Studies:** grounded in the disciplines of behavioural social science, particularly sociology, psychology, anthropology, and political science (MIT Sloan Management, 2007); Organizational Studies (also known as Organizational Behavior) is a distinct field of academic study which takes as its subject organizations, examining them using the methods of economics, sociology, political science, anthropology, and psychology. (It) is the study of individual and group dynamics in an organizational setting, as well as the nature of the organizations themselves. Whenever people interact in organizations, many factors come into play. Organizational studies attempts to understand and model these factors (wikipedia, 2007).
- **Cognitive Science:** interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology (Stanford Encyclopaedia of Philosophy, 2007); interdisciplinary study of the structures of the human mind. These structures include our sensory/perceptual apparatus, such as vision, audition, olfaction; internal mental processes such as language, thinking, reasoning and problem solving; motor control and the organization of skilled behaviour, such as speech and musical performance; memory; consciousness; attention; and many other aspects of mind. All of these subfields are clearly intertwined. Disciplines included are psychology, biology, neuroscience, philosophy, anthropology, linguistics, sociology, and computer science (Center for New Music and Audio Technologies, 2007).
- **Neuroscience:** scientific study of the nervous system, which was traditionally in the branch of biological sciences, but now includes the structure, function, development, genetics, biochemistry, physiology, pharmacology, and pathology of the nervous system, along with psychology, computer science, statistics, physics, and medicine (wikipedia, 2007).

Learning occurs at many levels. The multi-disciplines mentioned above will provide us with tools and methodologies to better understand how learning takes place and how that learning can be put into use. Neuroscience allows us to zoom in at the level of the nervous system and helps understand physiologically (physical and biochemical processes) how we are learning. On the other hand, Cognitive Science, which is at the end the study of information processing in our minds, allows us to better understand how we learn from accidents and how our mind makes decisions. Action Science promotes learning at the community-level and aims to form communities of practice. Organisational Learning provides a plethora of guidelines on how to learn at the organisational level, which is complemented by Organisational Studies, which allow us to better understand how organisations work.

One could extend the Organisational Learning concepts to higher levels, such as national governments and international institutions. Cross-fertilization of concepts from one multi-discipline to another can only enrich the understanding of learning processes.

2.2.3 Multi-disciplines related to Governance

Near *Governance* there are ten "multi-disciplines":

- **Complexity Science (or Complex Adaptive Systems [CAS]):** a dynamic network of many agents (which may represent cells, species, individuals, firms, nations) acting in parallel, constantly acting and reacting to what the other agents are doing. The control of a CAS tends to be highly dispersed and decentralized. If there is to be any coherent behaviour in the system, it has to arise from competition and cooperation among the agents themselves. The overall behaviour of the system is the result of a huge number of decisions made every moment by many individual agents[21] (Waldrop, 1992); theory of complex, self-organized systems, which consist of many closely connected and interwoven parts and which are difficult to understand and explain. The basic concept of complexity theory is that systems show patterns of organization without organizer (autonomous- or self-organization). Simple local interactions of many mutually interacting parts can lead to emergence of complex global structures (Fromm, 2004).
- **Post-Normal Science:** new conception of the management of complex science-related issues. It focuses on aspects of problem-solving that tend to be neglected in traditional accounts of scientific practice: uncertainty, value loading, and a plurality of legitimate perspectives … (it) considers these elements as integral to science. By their inclusion in the framing of complex issues, (it) is able to provide a coherent framework for an extended participation in decision-making, based on the new tasks of quality assurance (Funtowicz & Ravetz, 2006); metho-

21) Definition according to John H. Holland.

dology that is appropriate when “facts are uncertain, values in dispute, stakes high and decisions urgent”. It is appropriate when either ‘systems uncertainties’ or ‘decision stakes’ are high (van der Sluijs et al., 2003).

- **Decision Analysis:** includes philosophy, theory, methodology, and professional practice necessary to address important decisions in a formal manner… (it has) many procedures, methods, and tools for identifying, clearly representing, and formally assessing the important aspects of a decision situation, for computing the recommended course of action by applying the maximum expected utility action axiom to a well-formed representation of the decision, and for translating the formal representation of a decision and its corresponding recommendation into insight for the decision-maker and other decision participants (wikipedia, 2007).
- **Business Continuity:** a comprehensive managed effort to prioritize key business processes, identify significant threats to normal operation, and plan mitigation strategies to ensure effective and efficient organizational response to the challenges that surface during and after a crisis (ASIS International, 2005); Business Continuity Management is an holistic management process that identifies potential impacts that threaten an organisation and provides a framework for building resilience and the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value creating activities (BCI, 2005).
- **Emergency Management:** organization and management of resources and responsibilities for dealing with all aspects of emergencies, in particularly preparedness, response and rehabilitation…(it) involves plans, structures and arrangements established to engage the normal endeavours of government, voluntary and private agencies in a comprehensive and coordinated way to respond to the whole spectrum of emergency needs. This is also known as disaster management (UNISDR, 2004); Organized analysis, planning, decision-making, and assignment of available resources to mitigate (lessen the effect of or prevent) prepare for, respond to, and recover from the effects of all hazards. The goal of emergency management is to save lives, prevent injuries, and protect property and the environment if an emergency occurs [FEMA 1995, I-6] (NOAA, 2007).
- **Change Management:** the complete set of processes employed on a project to ensure that changes are implemented in a visible, controlled and orderly fashion; the activity, or set of activities, undertaken to

govern systematically the effects of organizational change (Georgetown University Information Services, 2007); describes a structured approach to transitions from a present to a desired state, in individuals, teams, organizations and societies…it has moved from a disjointed set of tools and models to a much more structured process that now has many organizations contributing to the academic and practical advancement of the field (wikipedia, 2007).

- **Transdisciplinarity:** recognition of the existence of different levels of reality governed by different types of logic; any attempt to reduce reality to a single level governed by a single form of logic does not lie within the scope of transdisciplinarity (First World Congress of Transdisciplinarity, 1994); with regards to the level of interdisciplinary relations, one can hope to succeed a higher level, which is "transdisciplinary" that would not be content to reach interactions or synergies between specialised research fields, but would place these links at the interior of a universal system without stable frontiers between the disciplines[22] (Piaget, 1972).
- **Risk Governance:** It includes the totality of actors, rules, conventions, processes, and mechanisms concerned with how relevant risk information is collected, analysed and communicated and management decisions are taken. Encompassing the combined risk-relevant decisions and actions of both governmental and private actors, risk governance is of particular importance in, but not restricted to, situations where there is no single authority to take a binding risk management decision but where instead the nature of the risk requires the collaboration and co-ordination between a range of different stakeholders. Risk governance however not only includes a multifaceted, multi-actor risk process but also calls for the consideration of contextual factors such as institutional arrangements (e.g. the regulatory and legal framework that determines the relationship, roles and responsibilities of the actors and co-ordination mechanisms such as markets, incentives or self-imposed norms) and political culture including different perceptions of risk. (IRGC, 2006).
- **Foresight Studies:** Foresight activities are policy-making processes, in which collective learning is developed in the S&T–related arena via

22) Transalted from French by author: "l'étape des relations interdisciplinaires, on peut espérer voir succéder une étape supérieure, qui serait "transdisciplinaire", qui ne se contenterait pas d'atteindre des interactions ou réciprocités entre recherches spécialisées, mais situerait ces liaisons à l'intérieur d'un système total sans frontières stables entre les disciplines" (Piaget, 1972).

interaction between industrial, academic, governmental and social actors. It operationalises interactive processes aimed at exploring openly and collectively possible futures (Tübke et al., 2001); Foresight covers activities aiming at: ***thinking the future:*** forecasting, technology assessment, future studies and other forms of foresight try to identify long term trends and thus to guide decision-making. Foresight that emerged in the recent years mostly in Europe aims at identifying today's research and innovation priorities on the basis of scenarios of future developments in science and technology, society and economy; ***debating:*** Foresight is a participative process involving different stakeholders. The latter may include public authorities, industry, research organisations, non-governmental organisations, etc. The process can be organised at different levels: cross-national, national, or regional. Open discussion between the participants is encouraged, for example in the form of panels; and ***shaping the future:*** Foresight aims at identifying possible futures, imagining desirable futures, and defining strategies. Results are generally fed into public decision-making (for example, which research priorities deserve public funding), but they also help participants themselves to develop or adjust their strategy (CORDIS Science and Technology Foresight, 2007).

- **Connectionism:** movement in cognitive science, which hopes to explain human intellectual abilities using artificial neural networks [also known as 'neural networks' or 'neural nets'] (Stanford Encyclopedia of Philosophy, 2007); Connectionism is an approach in the fields of artificial intelligence, cognitive science, neuroscience, psychology and philosophy of mind. Connectionism models mental or behavioral phenomena as the emergent processes of interconnected networks of simple units. There are many different forms of connectionism, but the most common forms utilize neural network models (wikipedia, 2007).

2.2.4 Multi-disciplines related to *Governance, Learning* and *Governance*

Near the towns of **Knowledge, Facts, Uncertainties** and **Values** there are five "multi-disciplines":

- **Knowledge Assessment:** provides information as to whether knowledge aims have been achieved, whether measures instituted by knowledge management have been successful, and to what extent knowledge aims are appropriately formulated…(it) does not mean assigning a monetary value to knowledge (Knowman, 2003);

In order to enforce better *governance* with regards to *learning* from *accidents* and dealing with them, one must look to multi-disciplines that have emerged from evolutionary theory and practice in various sectors. *Complexity Science* assists us in familiarising with complex systems, such as energy and transport systems, where many accidents have occurred and where these multi-level and multi-actor systems somehow have an *adaptive, learning* and *self-organising* capacity in the face of adverse situations. *Post-Normal Science* helps us to focus on value loading and plurality of legitimate perspectives during situations with high uncertainties (e.g. effects of nanotechnology *accidents*) and/or high stakes (e.g. impacts of a nuclear power plant *accident). Decision Analysis* equips us with procedures, methods and tools to systematically make decisions (e.g. regarding the choice of which mitigation action should be taken in the face of a potential technological *accident). Risk Governance* provides us with insight on taking risk-related decisions requiring multi-stakeholder participatory processes. This can be the case of potential accidents related to deep geological nuclear waste repositories, such as those presently planned for in Sweden.

Notions and concepts from *Business Continuity, Emergency Management* and *Change Management* will all assist us in better preparing for and responding to accidents, along with the various *learning* schemes practiced in these multi-disciplines. *Transdisciplinarity,* on the other hand makes us aware of the importance of interacting levels of interdisciplinary interactions. *Foresight Studies* provides us the capacity to systematically carryout new technology assessments and their potential impacts in various spheres of human and social life, whilst *Connectionism* sheds light to the various interconnections of *accident*-related systems through their conceptualisation of nodes and links. This enables us to appreciate the various degrees of connectivity of components in socio-technological systems that are characterised by *accidents* also. The analysis of nodes and links allows us to have a deeper understanding of processes and helps us identify strengths and weaknesses of systems and how to better address them.

- **Knowledge Management:** (it) caters to the critical issues of organizational adaptation, survival and competence in face of increasingly discontinuous environmental change ... it embodies organizational processes that seek synergistic combination of data and information processing capacity of information technologies, and the creative and innovative capacity of human beings (Malhotra, 1998); process for optimizing the effective application of intellectual capital to achieve objectives. In an organizational setting, this would mean a systematic approach to getting an organization to make the best possible use of knowledge in implementing its mission, broadly viewed as either sustainable competitive advantage or long-term high performance. From the individual viewpoint, this can be extrapolated to mean optimizing the effective application of the individual's knowledge (their potential and actual capacity to take effective action in varied and uncertain situations) to achieve the individual's professional and personal goals (Mountain Quest Institute, 2005).

- **Uncertainty Assessment:** systematic procedure to ascertain and quantify the uncertainty introduced into the results of a life cycle inventory analysis due to the cumulative effects of input uncertainty and data variability (ACLCA, 2006); part of the risk assessment process that describes, either quantitatively or qualitatively, the relative magnitude of uncertainties and their implications for the assessment (US-EPA, 2006).
- **Sensitivity Analysis:** study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input (van der Sluijs et al., 2003); analysis of the possible effects of adverse changes on a project. Values of key variables are changed one at a time, or in combinations, to assess the extent to which the overall project result, measured by the economic net present value, would be affected. Where the project is shown to be sensitive to the value of a variable that is uncertain, that is, where relatively small and likely changes in a variable affect the overall project result, mitigating actions at the project, sector, or national level should be considered, or a pilot project implemented (ADB, 2007).
- **Quality Assurance:** ISO 9000:2000 defines (it) as 'providing confidence that requirements will be met'; it can also be defined as 'the planned and systematic activities put in place to ensure quality requirements for a product or service will be fulfilled' (The Quality Portal, 2007); activity of providing evidence needed to establish confidence among all concerned, that the quality-related activities are being performed effectively. All those planned or systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality … (it) is a part and consistent pair of quality management proving fact-based external confidence to customers and other stakeholders that products meet needs, expectations, and other requirements ... it assures the existence and effectiveness of procedures that attempt to make sure - in advance - that the expected levels of quality will be reached (and it) covers all activities from design..., development, production, installation, servicing and documentation (wikipedia, 2007).

Everything that deals with *accidents, learning* and *governance* is related to the so-called *Pyramid of Knowledge* (Toffler, 1990; Vogy,[23] 1996; Fleming; Bellinger, 2004), which conceptualises the emergence of information from data (bottom of pyramid), the emergence of knowledge from information and the emergence of wisdom (top of pyramid) from knowledge. Another visual representation of this concept is shown in Figure 3, which is modified from a diagram made by Bellinger (2004). Thus, against this background, *Knowledge Management* assists us in better understanding and implementing organizational processes related to data and information processing towards the creation of a knowledge base in the field of *accidents* and *learning from accidents* to enforce better *risk governance. Knowledge Assessment* provides us with tools to monitor *Knowledge Management* processes. *Quality Assurance* provides systematic ways of ensuring the quality of data, information, knowledge and their collection, analysis and utilisation processes. *Uncertainty Assessment* methodically enables us to analyse uncertainties related to risk-related data, information and knowledge, whilst *Sensitivity Analysis* ensures that an analytical method is used to assess the robustness of results to uncertain assumptions or decisions regarding data, information and methods used.

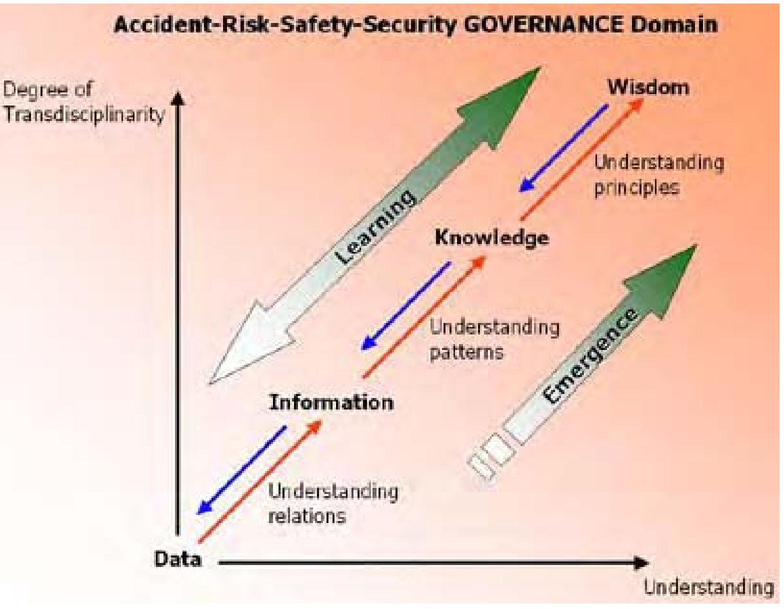

Figure 3 – Relationship between data, information, knowledge and wisdom in the Accident-Risk-Safety-Security GOVERNANCE Domain [modified from Bellinger (2004)].

23) Quoted by Madjoubi (1999).

3. Addressing complex processes

When dealing with learning from accidents in order to better address them, we are in the realm of complex processes. It is essential to choose a *reference starting point* (spatial and temporal) from which to begin, in order to better communicate ideas, concepts and processes. Reference starting points can be conceptualised as the design of a project or product, the construction of a facility, a change of management, etc. When dealing with accident, a common reference starting point used is the accident itself. Many methods[24] have been used to investigate accidents. Hallstrup & Funtowicz also describe a statistical and chaos approach (1992).

However, it can happen (and quite often does) that discussions tend to oscillate around points, i.e. components of a system or only a single system of many systems, resulting in lacking sight of the overall picture. Kastenberg (2002) observed this phenomenon in the risk analysis culture and offers a redefinition to address complexity that includes holism and self-organisation, which are two qualities of non-linear systems. He proposes a shift from the current risk analysis status quo, which derives from 19th Century philosophical theories of J. Bentham and J. S. Mills, which in turn took stock of Newtonian/Cartesian theories of the 17th and 18th century, which proposed a more linear view.

Thus, in order not get lost in the labyrinth of complex multi-level simultaneous processes we need to choose *reference starting points* of analysis. The choice of framing and scale is very important in understanding complex spatial and temporal processes, such as those occurring in the *Socio-tech-env* domain.

The first part of this section is dedicated to the importance of framing and scale awareness. This is followed by the need for attentiveness towards technology's pace. The third part of this section looks at networks, followed by a fourth sub-section addressing " fast-track" sectors as potential forerunners in promoting the lessons learning culture related to accidents. The last part of this section delves into the risk governance processes.

24) Munson (1999) describes the following types of accidentinvestigation concpets: i) single event; ii) chain of events; iii) stochastic events; iv) branched-tree perception; v) management oversight and risk tree; vi) fault tree analysis; vii) Haddon Matrix; viii) barrier analysis; ix) events and causal factors charting; x) multi-linear events sequence; xi) change analysis; xii) managerial failures approaches; xiii) root cause analysis.

3.1 Concepts to bear in mind

The scope of this paper is not to go in depth on framing and scale issues, which are intricately linked, but there is a need to dedicate a few paragraphs on them.

3.1.1 Framing

When a problem is perceived in the *socio-tech-env* context, e.g. the occurrence of the recent blackouts in the European Union on the night of 4 November 2006, an interactive process is triggered with the intent of understanding what happened and identifying ways to resolve it. The start of this process, i.e. problem framing, is very crucial, as it will strongly influence the quality of the process and its outcome. It is important to bear in mind that different problem definitions *could* lead to different ways of resolving them and different outcomes.

In the above-mentioned example, it was reported that a ship required safe passage underneath an overhead electricity line that crosses the Ems River in Germany (BBC [2006]; Bloomberg [2006]; CNN [2006]; Reuters [2006]). According to E.ON[25] (2006), this planned deactivation of the power line triggered a grid overload in northwest Germany, which had a domino effect across the European grid causing temporary power outages in Germany, France, Italy, Portugal, Spain, The Netherlands, Belgium and Austria (Reuters, 2006).

The accident *could* be interpreted as having safety and reliability characteristics. Within an electrical grid, it can happen that safety and reliability goals do not necessarily converge. In the above-described accident, the achievement of a safety-related goal had led to the failure of a reliability-related goal. The framing of this problem could be set within a reliability context, which *could* result in actions towards solutions favouring reliability at the expense of safety, or the opposite framing approach could be implemented. The framing chosen by E.ON *would* influence their resulting decisions once the results of the accident investigation are received.

3.1.2 Scale

Scale is another important concept that should be taken into account when learning from accidents. At what level are we learning? At what scale must we implement actions based on lessons learned? Do our minds have the capacity to easily zoom in and out during learning and governance processes?

25) E.ON is a German energy service provider. For more information, see: http://www.eon.com (retrieved 16 November 2006).

Zooming

I would like to attempt an explanation by using an analogy. I am sure that many of you have played around with web applications like "Google Maps"[26]. Besides being fun, it is a useful tool to explain the issues of scale. It could be used to solve many problems, or in other words, assist you in making decisions, at different scales.

Concrete examples are always useful in trying to communicate ideas and concepts, so here are my proposed ones. Imagine you would like to know the distribution of the continents with respect to each other, or the countries bordering the Pacific Ocean. Then all you need is a low-resolution map that does not require that much detail. However, you would need a much higher resolution, with more details, if you would like to know what route to take to get you from Alkmaar, in The Netherlands to a town called Taino, in Northern Italy. These examples are quite straightforward. It is clear from these examples how the framing of the problem is linked to the scale at which one tackles the problem.

Depending on what your problem is and how you will frame the problem, you will then be able to choose the appropriate scales of analysis, bearing in mind also that different scales may show different understandings of the problem framed.

Panning

I will make use of the same analogy used in the *Zooming* section above to explain *panning*. Another important function in "Google Maps" is *panning*, which allows us to navigate to the areas surrounding the initial scale and area of analysis. This is also very important in understanding processes, as boundary areas may have an influence on the area under study (given a particular scale).

Thus, once a problem is framed, e.g. in the context of learning from accidents to better manage them, one should combine zooming and panning approaches to better understand the various multi-level simultaneous processes occurring. As the analysis progresses, it is not unlikely that the problem must be re-framed once again.

Understanding accidents, learning from them and dealing with them are complex, dynamic and iterative processes that require the cognitive flexibility of being able to downscale and upscale one's analytical approach according to the framing of the issue at hand.

26) See http://maps.google.com (retrieved 20 February 2007).

3.2 An ode to technology's pace

This section will look at the temporal dimension of technology that is another complex process that needs to be borne in mind when dealing with impact assessments of potential risks (*a priori* analysis) and when analysing accidents in the light of improving governance (*a posteriori* analysis). Technology is evolving at a very fast pace. Figure 4 provides an idea of how fast this is occurring. It is based on W. B. Arthur's Scientific American article entitled: *How fast is technology evolving* (1997).

You will notice that there are two timelines portrayed: *evolution* and *inventions/discoveries.* The former portrays key events since the existence of the Earth, approximately 4.6 billion years ago, shown using the Arthur Scale[27], which uses 20 November 2006, 12 pm as the reference date and time from which the calculation is made. The latter timeline shows inventions and discoveries that can be correlated to the evolution timescale using the Arthur Scale. For example, the invention of the nuclear power reactor in 1951 can be correlated to the Cambrian explosion in the evolution timescale, whilst the development of the mirror TV can be correlated to approximately the appearance of Homo erectus.

From Figure 4 below, it can be deduced that technology is evolving approximately 10 million times faster than natural evolution. It is clear that within the *socio-tech-env* domain, the quick pace of technology triggers changes in society, which uses new technologies and adapts to the multifaceted ripple effects they have on life on Earth (society and environment). As there is a lag between technology's pace and the resulting adaptation of society, man is faced with many uncertainties to deal with, particularly when preparing legal acts that regulate our various types of interactions with such technologies. In addition, man has to learn and adapt to new technologies and can him/herself be the cause of accidents resulting from the man-machine and society-technology complex interactions.

Technology, which is man's expression of his/her creativity, can also be the cause of his/her vulnerability. Our use of technology and the resulting networks that emerge from it, make us too dependent. As time goes by, we forget how to cope without such technology, which becomes our Achilles heel.

27) The Arthur Scale is obtained by dividng the years by 105. This was done to enable comparison with the inventions/discovery timeline.

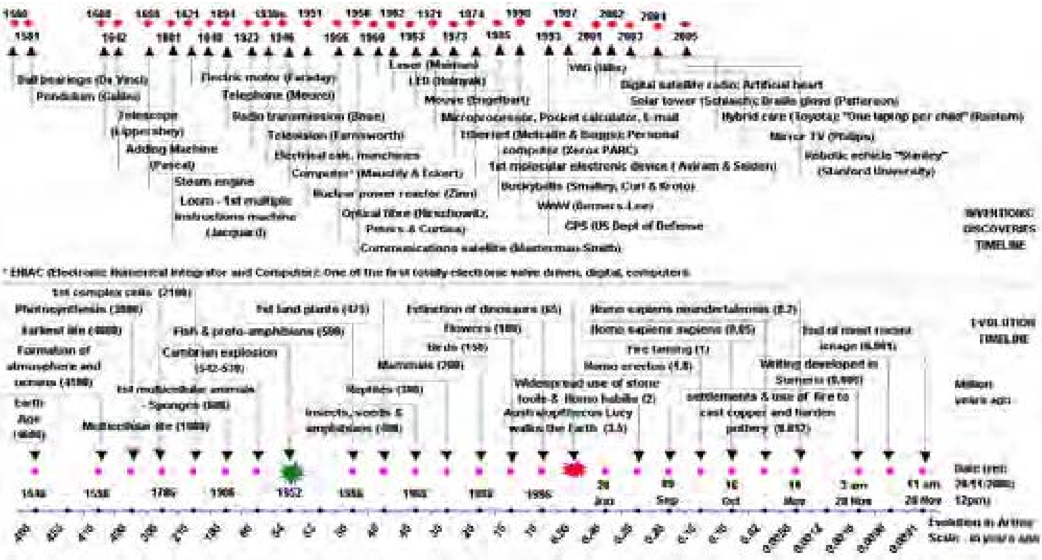

Figure 4 – Invention/Discoveries and Evolution timelines, based on and modified from Arthur (1997), which attempts to show the quick pace of technology.

The increasing complexity of technology and its pace of development, coupled with the increased interconnectedness and coupling of systems in society, make it difficult for society to cope and keep pace with the above, leading to a lag between the above and development of standards and regulations that are able to govern the related co-evolving risks and uncertainties.

Technology advancement does not necessary mean that our increased knowledge and experience imply that we can cope better with accidents. It means that: 1) we have improved statistics on similar known accidents; 2) it may provide insight on potential known unknown accidents, and thus allow catering for those types of accidents. However, the unknown unknown accidents are still there. New technologies tend to allow the burgeoning of such unknowns, thus increasing the uncertainty component, which is not easily dealt with.

The challenge ahead is better understanding and learning about the complex interacting processes between networks in socio-tech-env domain, coupled with targeted analyses that assess these systems under stress in order to foresee potential accidents and devise actions to cope with them. It is also essential to look beyond the borders of the issue at hand and identify potential cascading effects in the inter-related sectors of the Socio-tech-env domain.

3.3 A tribute to networks

If we observe our world around us, we will notice that we find ourselves linked to many networking webs:

Infrastructure:

- ***Energy:*** electricity grid, oil and gas transmission and distribution pipelines;
- ***Transport:*** railways, highways, maritime networks, aviation networks;
- ***Information and Communication:*** satellite networks, telephone networks, internet;
- ***Other:*** water distribution systems, stock market systems.

Social:

- ***Physical:*** Universities, Churches, Businesses, Clubs, Governments, International Organisations, etc.;
- ***Virtual:*** Networks of Excellence, Blogs, Discussion Fora, Internet Communities.

Bio-ecological:

river networks, ecological networks, cellular networks of the human body, food chain, etc.

We are living in a highly dynamic and high density networked world, which emerged in the history of time and is still evolving and changing. *"As humanity becomes increasingly dependent on power grids and communication webs, a much-voiced concern arises: … how reliable are these types of networks* (Barbási & Bonabeau, 2003)?

To answer this question, I will briefly describe a new science that emerged in the later half of the twentieth century: Network Science. According to Barbási & Bonabeau (2003), all complex networks were treated as completely random in the last 40 years, which was pioneered by the early works of Paul Erdős and Alfréd Rényi who published an article in 1960 (see references), which described how systems could be modelled by connecting their nodes with randomly spaced links (random networks). Their approach contributed to the further elaboration of graph theory[28].

28) The earliest publication on Graph Theory was from Leonhard Euler on the Seven Bridges of Königsberg, which explained that it was not to walk with a route that crossed each bridge of the seven bridges exactly once, and return to the starting point (Barbási, 2002).

Recent work by Barbási's team[29] at the University of Notredam has led to the discovery of scale-free networks. These scale-free networks differentiate themselves from random networks with the following characteristics (Barbási & Bonabeau, 2003):

- Existence of hubs[30],
- Resilient to accidental failures, but vulnerable to coordinated attacks (this point provides insight to the question posed above, i.e. how reliable are these types of networks?),
- Further research in networking science could increase our understanding of the various behaviours of such networks, which could in turn lead to potentially innovative applications in various sectors, such as:
- ***Information Technology:*** new ways to circumvent coordinated attacks by hackers on the internet, novel approaches to minimise the effect of viruses diffused on the internet etc.;
- ***Medicine:*** improve vaccination campaigns against viruses, by better understanding and identifying the "hubs" in social networks, creation of tools and methods to map out networks within the human cell to uncover and control side effects of drugs, ways to identify molecule "hubs" in diseases to develop new drugs targeted to destroy them, etc.;
- ***Business:*** improve our understanding of social networks to identify social "hubs" that can be targeted to efficiently diffuse, as quickly as possible, products, services, philosophies, etc., increase knowledgebase on how companies, industries and economies are connected so as to avoid cascading financial disasters or minimise their effects.

Against this background, there appears to be two types of networks that can be observed: random and scale-free. Examples of the latter have been provided above, whilst those of the former are: crystal lattices, the U.S. highway network and the U.S. electricity grid (Barbási & Bonabeau, 2003). Accidents in random networks result in a lower robustness of the system resulting in the creation of isolated nodes, due to the non-existence of "hubs".

29) See http://www.nd.edu/~networks (retrieved 20 February 2007).

30) Hubs are special nodes that have a very high number of connections to other nodes, via links. It is this characteristic that gave the name "scale-free" to these types of networks.

Taking stock of advances in network science to better understand these types of networks will assist us in better addressing *accidents, learning* and *governance* aspects related to them. We are already in a new regime with regards to understanding accidents and learning from them thanks to advances in many areas that led to the creation of new "multi-disciplines" that promote interdisciplinary processes (cfr. Figures 1 and 2). The era of Information Technology has provided a quantum leap in the collection, organisation, analysis and implementation of data and their consequent transformation to information and knowledge.

We are now entering an era where we are carrying out research on *Nano-bio-info Technology*[31], which will open new challenges regarding *accidents, learning* and *governance*, but which also have the potential for providing benefits to mankind. An example of a spin-off at the convergence of these three technologies is *Affymetrix*, which is a concept developed by Stephen P. A. Fodor in the 1980s to use semiconductor manufacturing techniques to create GeneChips that allow quick scanning of particular genes in a biological sample. A single chip has the ability to carry out thousands of experiments in parallel, but can only be used once[32]. Imagine the potential impacts this could have in many sectors of society and how important it is to take on board the experiences in network science to assist us in carrying out a priori analysis of these potential impacts, complemented by a posteriori analysis, in case of investigations of root causes of anomalous events!

3.4 Fast-track sectors: the potential harbingers of the lessons learning culture

Accidents and disasters have been happening since man has started to inhabit the Earth. History is a repository, which offers a plethora of experiences from which to fortify our lessons learning culture to address such accidents in the various sectors in society.

Every sector generally offers three types products/services (modified from Haastrup & Funtowicz[33], 1994): *intended, known unintended* and *unknown unintended.* The various experiences and processes that constitute a sector's knowledgebase should be shared with other sectors (cross-fertilisation of lessons learned and good practice). If you observe the various sectors in society, you would notice different management paces. Table 2 below is a tentative grouping of selected sectors into "fast-track", "normal" and "low", which provides a differentiation of management rhythm with

31) Nano-bio-info Technology is an emerging technology combining experiences and knowledge from three technologies: nanotechnology, biotechnology and information technology. It applies tools and processes nano/microfabrication to build devices that study biosystems to better understand life processes at the nanoscale. See http://www.nbtc.cornell.edu (retrieved 20 February 2007).

32) See http://www.affymetrix.com (retrieved 20 February 2007).

33) According to Haastrup & Funtowicz there are two outputs: intended and unintended.

regards to *learning from accidents*. The term "fast-track" is not intended to have a high frequency of occurrence of accidents connotation, but it aims to highlight the **fast management pace** in these sectors resulting from high interconnectedness, coupling, complexity, technology drive/effort and stakes. It is not surprising that risk management, as a discipline, developed rapidly in the financial sector (Bernstein, 1996) due to the management of high economic stakes.

Intuitively, the Clinical/Medical, IT, Telecommunications, Chemical and Civil Protection sectors are also characterised by a fast management pace, resulting in the generation of more opportunities for *double-loop learning* (cf. Footnote 12 in sub-section 2.1.3), thus potentially rendering them the potential harbingers of the lessons learning culture. These are the sectors we should be looking at in order to take stock of lessons learning experiences and processes that can be implemented in our line of work. Solving the problem (i.e. rehabilitation and action to return to normal conditions and operations similar to those before the accident took place) is only part of the learning process and is only a *single-loop learning* (cf. Footnote 12 in sub-section 2.1.3).

Table 2 - Tentative grouping of sectors into "fast-track", "normal" and "special" with regards to management pace.

Sector	Interconnectedness[34]	Coupling[35]	Complexity[36]	Technology drive/effort	Stakes
Fast track					
Financial	High	Tight	High	Medium	Economic
Clinical/ Medical	High	Tight	High	High	Human
IT	High	Tight	High	High	Human, economic
Telecommunications	High	Tight	High	High	Human, societal, economic, environmental
Chemical	High	Tight	High	Medium	Societal, economic, environmental
Civil Protection	High	High	High	Medium	Societal, economic, environmental

34) Interconnectedness within Socio-tech-env domain.

35) Coupling of components.

36) Complexity of components.

Transport networks					
Aviation	High	Tight	High	High	Human, societal, economic
Aerospace	Medium	Tight	High	High	Human, economic
Normal					
Energy nodes					
Nuclear power plant	Medium	Medium	High	High	Societal, economic, environmental
Oil processing plants	Medium	Medium	Medium	Medium	Societal, economic, environmental
Gas processing plants	Medium	Medium	Medium	Medium	Societal, economic, environmental
Carbon power plants	Medium	Medium	Medium	Medium	Societal, economic, environmental
Energy networks					
Electricity	High	Tight	Medium	Low	Societal, economic, environmental
Gas	High	Tight	Medium	Low	Societal, economic, environmental
Heat	Medium	Medium	Medium	Low	Societal, economic, environmental
Transport networks					
Maritime	Medium	Tight	Medium	Medium	Human, societal, economic
Road	High	Medium	Low	Medium	Human, societal, economic
Rail	High	Medium	Low	Low	Human, societal, economic
Low					
Energy nodes					
Hydro	Low	Loose	Low	Low	Societal, economic, environmental
Solar	Low	Loose	Medium	Low	Societal, economic, environmental
Wind	Low	Loose	Low	Low	Societal, economic, environmental

Table 2 (cont.)

Improved learning processes from such "fast-track" sectors will increase the probability of improved governance processes. It is especially important to already think in advance with regards to newer "fast-track" technologies, such as nano-bio-info technology, about its potential risks, benefits and uncertainties and the way these will impact on the socio-tech-env domain. This will indeed require inter-disciplinary visionary foresight studies in a much-unexplored territory to anticipate good governance practice.

Moreover, There is also a need for actors (directors, managers and employees of institutions) in each of these sectors to reflect critically on their own behaviour and identify the ways they often inadvertently contribute to the sector's problems, and then change how they act (Argyris, 1991).

3.5 Risk governance processes

Risk governance takes centre stage in this sub-section. It will initially provide a rationale vis-à-vis the importance of risk governance, which will be followed by a few paragraphs describing the important ingredients towards achieving good risk governance.

3.5.1 Why is risk governance important?

Governance processes addressing risks have existed since the dawn of humanity. In the beginning risks were mainly environment-related (e.g. adverse weather conditions and lurking predators), but as tools developed and as technology and society evolved and interacted with the environment, so did the typologies of risks co-evolved (cfr. Figure 3), along with the resulting accidents and disasters. Thus, the amounts of technological risks have increased in time and risks have become more complex and multi-faceted, such as flood risks. Are they natural, technological or man-made? One could argue that they are all of them[37]. Life is filled with different typologies of risks, which have evolved in space and time and man will always attempt to deal with them in some manner or other.

37) A flood could be the result of the combination of changing climate (natural), man's over-exploitation of land coupled with impermeabilisation of the ground due to urbanisation, thus increasing runoff (man-made) and technological (could be triggered by dambreak). It is not even as straight-forward as this, because even climate change has a degree of man-made and technological there too, as power plants (technological) are one of the main contributor's to climate change, along with inefficient and inconclusive governance (man-made). When I was in Middle School, we were taught about pollution and how it could affect climate. Over 25 years down the line, all global governance has to offer for the moment is the Kyoto Protocol. When I observe how climate has changed these last years, I feel that we need more incisive decisions to be made requiring ownership from all citizens and willingness to sacrifice for the common good and future generations.

We live in a world where traditional mechanisms of co-ordination are faced with irreducible factors of complexity in the context of technological activities and their related risks, e.g. *Nano-bio-info Technology* (see Footnote 49). In our attempt to address this challenge, traditional institutional frameworks and environments can contribute to create and/or to amplify ambiguities, uncertainties and distrust among the concerned stakeholders (TRUSTNET IN ACTION, 2006). Thus, the role of governing bodies is crucial in terms of obtaining efficient and incisive results.

Governing bodies (international, national, regional, local, corporate) have established frameworks encompassing rules, processes and behaviours regarding the boundary conditions of their powers (i.e. **why, when, where** and **how** they can interact with **who** and regarding **what**). It would be recommended that such governing bodies, at whatever level, promote pluralistic involvement, interdisciplinary processes of expert interaction, consolidation of interactive and efficient dialogue processes and foster quality-driven processes (TRUSTNET, 1999).

3.5.2 Towards achieving good risk governance

According to TRUSTNET (1999), good governance implies the promotion of the following practices below.

- pluralistic involvement,
- interdisciplinarity of expertise,
- duration of the dialogue process,
- quality of risk governance.

In a "globalised" realm where events like hurricanes[38] are able to have ripple effects across the world; where the quick pace of new technology development demand ethical discussions and regulatory action to address risks and related uncertainties; where complex processes are simultaneously interacting at all levels resulting in competing pressures on society; where administrative borders have become insignificant in the face of such complexities (trans-boundary risks); now is the time to build momentum in promoting the practice and development of a new regime of risk governance.

38) Hurricanes Katrina and Rita together destroyed 113 oil platforms and damaged 52 others; 457 pipes were damaged (Minerals Management Service, 2006a; Minerals Management Service, 2006c); 9 refineries in the Gulf Coast (United States Department of Commerce, 2005), leading to the decline of oil and gas production respectively, by 24% and 18% (Minerals Management Service, 2006b) for a period of six months.

It is essential that a participatory approach of all interested and affected actors be implemented to ensure a democratic process towards the establishment of regulatory initiatives. There is the need to combine available scientific knowledge and good practice with the involvement of relevant stakeholders. This would trigger ownership amongst stakeholders who should not feel alienated from the decision-making process. Within this process, clarity should be made regarding roles and boundaries of each participant.

It is essential to harness our ability to learn from past accidents and disasters and apply generic concepts to specific situations. We will not be able to predict the exact type of future accident or disaster nor the related problems it will create. However, we can strive to develop generic guiding principles and better learning and governance processes to better prepare for such occurrences and to better respond to them. This should be complemented strongly by the promotion of interdisciplinary expertise to allow the cross-fertilisation of knowledge bases from different disciplines to be utilised in decision-making processes regarding a given risk in one's own field of experience.

Dialogue processes cannot only be triggered by catastrophes. It must be a continuous process that should be embedded in all governance processes. Communication processes should be aimed to improve the different publics' understanding and perception of risks and implies access to information (i.e. collection, analysis and quality assurance of information), public participation in decision-making (i.e. multi-stakeholder interaction and discussion of risks and their related impacts) and access to justice in environmental matters (i.e. awareness of citizens' rights, building of their trust and access to administrative or judicial procedures), as advocated by the Aarhus Convention[39].

Improving communication processes are not enough to improve risk governance, as there is a paucity of evidence supporting the notion that improved risk communication has: i) reduced the gap between technical risk assessments and public perceptions ii) facilitated decisions regarding complex risks, such us those linked to nuclear waste management. *The limited effectiveness of risk communication efforts can be attributed to the lack of trust* (TRUSTNET, 1999)[40]. Enhancing the quality of risk governance processes is thus, also intricately linked to gaining the various publics' trust. Decision-makers should increase their attention to increasing the publics' trust in governance processes by upholding: better involvement and more openness and better policies, regulation and delivery (European Commission, 2001).

39) Adopted in Aarhus, Denmark on 25 June 1998. See http://www.unece.org/env/pp/documents/cep43e.pdf (retrieved 20 February 2007).

40) TRUSTNET quoted a paper from Slovic and MacGregor ("The social context of risk communication" - Paper Decision research, Eugene, OR, 5 May 1994).

4. Closing remarks

Why is it important to learn from accidents? We want to learn from accidents in order to better understand such events, to forecast scenarios of potential future events, to better optimise resources to manage risks of events (i.e. prevent, mitigate prepare and respond). These are not easy tasks in our dynamic and complex world.

How may we improve our risk governance practice? Firstly, we should acknowledge that we are all participants in our evolving "risk society" where "consequences of scientific and industrial development are a set of risks and hazards" that implores a "reflexive" approach when dealing with different forms of knowledge. In this *reflexive learning process,* stakeholders negotiate different epistemologies and discourses interactively amongst themselves (Beck, 1992; Craye et al., 2005). We should implement risk governance approaches that aspire to achieve "reflexive modernity" process, which is Beck's third stage of social change required to address our dynamic and multi-faceted risk landscape.

It is therefore of utmost importance to shift from the more traditional science-based risk governance practices where governance processes strictly depend on hard scientific facts (Cross, 1998) to a more participatory approach where diversity of experiences, knowledge and values are captured (Guimarães Pereira, 2006). Moreover, we should move from the uncritical puzzle solving within an unquestioned "paradigm" of "normal science" (Kuhn, 1962) to the management of complex science-related issues of "post-normal science" (Funtowicz & Ravetz, 1993).

Furthermore we should be aware of the following issues when carrying out risk governance in the face of accidents:

- different languages and perceptions of risk;
- multi- and inter-disciplinary approaches;
- flexibility to downscale and upscale one's analytical approach according to the framing of the issue at hand that needs management;
- interconnectedness and interdependencies of systems, whereby a short-term solution could evolve into a long-term problem, or a technical fix in one sector could cause troubles in another sector;
- cross-sector learning and sharing of experiences;
- every solution and action always comes with a degree of uncertainty, which requires assessing, thus risks and benefits have related uncertainties;

- promotion of informed-decision-making via democratic and participatory processes.

I have endeavoured to paint a picture of my chosen Accidents-Learning-Governance landscape. I hope that I have achieved my aim at the start of this paper and that I have increased your curiosity to join me in this heuristic odyssey exploring and learning about this dynamic, complex and evolving landscape.

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Disclaimer

This paper is a work in progress. The views expressed are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission. The information was compiled from a wide range of sources, and although I have aimed to present them as accurately as possible, there may be errors and omissions. I would be happy to receive any comments and suggestions on how this paper can be improved or changed.

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Marcus Johansson

Biography

Role in the Project

Writer

Work/studies today

I have worked as an analyst at the Swedish Rescue Services Agency (SRSA), National Centre for learning from Incidents ans Accidents since the spring of 2005 with 50 % of my time designated for research. The research deals with factors that promote and inhibit learning and reform after crisis.

Beside my research efforts I am involved in a wide range of projects within the domain of learning from accidents. My current projects include connecting societal factors (e.g. drug use, age structure) to the incidence of frequent accidents as well as coordinating the SRSA:s studies of major accidents and disasters.

Background

I was born in 1980 and have an undergraduate degree in fire protection engineering and a graduate degree in risk management and safety engineering from Lund University. I also have one semester of studies at the University of Maryland in the U.S. and have taken extra curricular classes in different disciplines including philosophy and psychology.

Before joining the SRSA I had a short term position at Lund University, working with learning from natural disasters.

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Collaborative Learning from Accidents

– Accidents as impetus for renegotiation of practice

Introduction

How can we prevent the reoccurrence of accidents? This has been a question under debate for several decades and the answer has evolved over the years from a sole focus on technology and legal prosecution to embracing both the human and social dimensions of reality. However, the way to facilitate learning from accidents has remained largely unchanged over the years. With a strong influence of taylorean production philosophy one has treated human action in very simplistic terms where changes in behaviour are thought to be achieved by simply changing routines. This, despite the fact that accident investigation after accident investigation show that routines are often not followed in practice (e.g. Reason, 1990).

Much of the available ethnologically inspired research on work place practice (e.g. Brown & Duguid, 1991; e.g. Orr, 1996; Suchman, 1987) has criticized the one-sided focus on canonical practice (e.g. routines) in most organizations, neglecting the more opaque adjustments that are needed to perform the work. Traditionally all such adaptations have simply been seen as "deviations" and one fails to realize that reality is more complex and dynamic than can be captured in routines (Suchman, 1987). Bourdieu (1977) provides the analogy of travelling in the terrain compared to seeing the route on the map. It is extremely important to have a good map to follow, but maps fail to show many important aspects of reality such as road works, earthquakes, personal fatigue and inaccuracies on the map itself. The same is true for routines. A routine can be very useful, but one should not fall for the temptation of seeing it is as capturing all relevant aspects of practice.

This paper will elaborate briefly on current scientific knowledge on how practice is formed in the workplace. Interested readers should find a much deeper discussion on this topic in, for example, Brown and Duguid (1991), Bourdieu (1977) or Orr (1996). Taking these discussions as a point of departure, renegotiation of practice with a special focus on accidents will be presented. The paper will end with a brief presentation of a work process that can be used to facilitate this renegotiation in the wake of an accident.

On accident investigations

Currently in our society, two distinct types of accident investigations are most frequently conducted. The first, and probably oldest, is the legal perspective in which one tries to find responsible individuals or organizations. A variant of this type of accident investigation is political inquiries. The second type of accident investigation is aimed at identifying the causes of the accident (traditionally in technical terms) and recommending actions to reduce the risk of reoccurrence.

Conducting accident investigations from a legal perspective is frequently criticized by proponents of learning since there are good reasons to believe that this influences information sharing in a negative manner (e.g. Stern, 1999). This may therefore lead to potentially valuable lessons being missed. In my opinion the discussion is quite one sided and one often neglects the potential positive effects on a societal level. Postponing or even cancelling the blame allocation process in many instances can definitely be justified, but one has to weigh up the potential gains against the potential losses of doing so. A few years ago a small boy was killed by a falling icicle in Stockholm and this led to the owner of the building being prosecuted for not clearing the roof of icicles. I was involved in a discussion about whether this was the right thing to do or not. My position was, and still is, that the legal investigation and verdict are indeed very important for improving safety. This is because there are many potential actors that could have prevented the accident, for example the company that designed the roof or the road administration that could have designed the pavement in another way. However, when multiple actors can prevent an accident it is important to agree on who is responsible for doing so. In this case the accident received much media attention and the verdict probably led to many building owners realizing their responsibility for keeping their roofs free from icicles. This can also be seen as a form of learning from accidents comprising a wider group then just the building owner directly concerned. The verdict led to the allocation of responsibilities between actors being stipulated. The importance of this can not be overemphasized. As the saying goes, “shared responsibility is no responsibility”. I do not say that we should go back to a system focused on blame allocation, but I believe that the discussion should be more nuanced and people in the safety field should also realize the positive effects of blame allocation. From that point the discussion should turn into a discussion on which strategy would be most appropriate in any given situation.

The other type of accident investigation is investigation for learning. This has been by far the most elaborated within the safety discipline, so I will not elaborate on the subject in any great detail. The distinguishing feature of this type of accident investigation is that an outsider is assigned to develop deeper knowledge of the roots of an accident. The depth of the inquiry varies substantially; from simple deviation reports to several year long inquiries by investigation boards or researchers. The guiding questions in these investigations are "Why did it happen?" and "How can we prevent it from happening in the future?" Research level investigations usually focus on the former question and often generate substantial knowledge on the patterns that ultimately led to the accident (e.g. Vaughan, 1996). More practice oriented investigations usually place more emphasis on the latter question since they are more aimed toward direct intervention. The recommendations are often directed toward the formal organization where changes in routines and technological systems are very prominent.

The general approach has proven quite effective in changing the technical environment. To name just one extremely important example, a number of accident investigations were initiated following accidents in the 50s when airplanes were breaking up in mid-air for no apparent reason. Careful investigations led to the conclusion that the sharp edges of the airplane windows resulted in higher levels of stress than the airplane body could cope with. Because of this, from that point, airplane windows have always been constructed with rounded edges. There are numerous examples of this kind in which careful investigations have led to important changes in the technical environment. These types of changes are quite frequently criticized by "modern" accident investigators that emphasize the role of the organization. However, a recent study of intervention against frequent accidents (e.g. falls, traffic) has shown that technical changes are generally far more effective than information and legislation (Lund, 2004). One should of course not neglect the influence of, for example, management on the conditions that lead to an accident, but one should also not understate the effectiveness of "simple" fixes such as changes in the technical environment.

One more problematic aspect of classic accident investigations is how to influence worker practice in the wake of an accident. There is of course a number of ways through which management influences behaviour such as policies and bonus systems, but it is extremely difficult to connect these influences to a specific accident. The accident may provide a policy window to influence these aspects of the organization (Boin et al., 2005), but it is hard to prove that these changes really would have prevented the accident had they been in place. Because of this, one of the most prominent, if not the most prominent, recommendations in the wake of an accident investigation concerns changes in routines. It is easy to show that if the work had been conducted in accordance with these new routines, the accident would have been prevented. However, as the very same investigations show, routines are very frequently violated. As I see it this poses a serious dilemma for the future of accident investigations. Time after time it is demonstrated that not following routines is a prominent cause of accidents (Reason, 1990), but still, the way suggested to influence behaviour is yet more new routines.

As I see it, there are two potential directions to resolve this dilemma. Either one argues that we should get better at enforcing routines. This will require a substantial control regime in the organizations where deviations are identified and punished. An alternative route to pursue is to argue that routines, generally, do not acknowledge the complexity and the necessary trade-offs of real life and that they are therefore virtually impossible to employ in practice.

I believe that the former, even if theoretically achievable, is not the route to take for the future. Rather, I believe that we must get better at developing our routines in a way that makes them useful in everyday practice. One very illustrative example of the potential problems with the way routines are developed at present is the 2005 Swedish metro strike. When this strike ended the workers threatened (!) management that they would follow all routines. Everyone, from workers to high management, knew that this would make work impossible.

Before proceeding with the argumentation I would like to comment on the term "safety culture" that has been widely spread in our field following the Chernobyl nuclear disaster. It is almost hard to find an accident investigation that does not conclude "deficient safety culture". What lies behind this label is very different (Guldenmund, 2000), but one common factor is that workers did not follow safety procedures. In the light of the former paragraph one has many reasons to question this conclusion. The formal organization can easily prescribe routines that are almost fail proof, but these routines can be impossible to employ in practice since they are developed almost solely with one goal, safety, in mind. The wide variety of competing goals and the variability of reality are not taken into account. One critical way to look at these safety routines is as safeguards for the formal organization. If an accident occurs you will have no problem in finding a procedure that was violated and you can therefore conclude "operator error" or its modern variation – "deficient safety culture". By doing this, the formal organization and people at higher levels are generally considered to be without blame. I do not say that the emergence to term safety culture is all bad, far from it. I believe it is very important that we stress that the perceived importance of safety, throughout the organization, is very important, but one should take good care before reaching the conclusion that deficient safety culture was the primary cause of an accident.

This chapter has aimed towards illustrating problems when it comes to using accident investigation to influence behaviour. In the wake of these problems, the following chapter will focus on how practice is being formed in the work place.

On formation of practice

There are quite a few studies that aim to describe how work practice is actually formed and maintained in the work place. The methods are often inspired by ethnological methods since this provides an opportunity to talk to workers and to see how they actually perform their work. An early review of this type of research is available through Burawoy (1979), but the single most influential work is probably Orr's (1996) famous study of service technicians[1].

What has been made clear by this research is that reality is generally far more complex than was commonly assumed within the taylorean production paradigm (c.f. Taylor, 1911) and negotiation between goals are constantly needed even at the lower level of an organization (Suchman, 1987). The routines provided by the organization do not support actors in these trade offs between goals since these routines are often developed with the focus on solitary goals, such as quality or safety. This necessitates the violation of routines that were clearly illustrated in the metro example mentioned above. The outsider's luxury of focusing on single goals is not shared by the insider who always needs to perform this negotiation with

1) This was clearly illustrated by the special edition of the journal "Organization Studies" (2006, volume 27 Issue 12) dedicated to the ten year memory of the publication of his book.

reference to, for example, time, efficiency and economy.

Needless to say, the formal organization has a great role in influencing this negotiation. I have experience from an organization that has “Safety first!” as its slogan, however, when one looked closer into the workers bonus system, this was based on production rather than safety. The signs that aim to stress the importance of safety are quite weak when bonus systems state otherwise.

As Orr (1996) and others have shown there are strong social processes at play in the work place. The negotiation between goals is not carried out so much by individuals maximizing benefits as by social groups. This leads us to the very important aspect of safety that is covered in the papers by Kenneth Petersen and Jean-Christophe LeCoze in this anthology, the social construction of reality. I will only touch on this subject very briefly; the interested reader should refer to these papers.

Rasmussen (1997) has presented the so called Brownean-motion analogy to illustrate the concept of organisational drift towards failure as a result of the adaptive behaviour that shapes practice. This analogy very clearly illustrates what this paper has tried to capture when it comes to adaptation to perceived relevance of competing goals. However, it is also important to acknowledge the social dynamics that form and maintain practice. This has not been emphasized enough in our field.

In a group of people, regardless if in the workplace or in other contexts, a shared repertoire or a mental model of reality quite quickly evolves. This socially constructed reality give answers to questions of what actions are appropriate in which situations (Berger & Luckmann, 1991). When related to safety the socially constructed models give answers to what behaviour is safe and what is not. Influencing this “reality”[2] is an extremely difficult and slow process since people are very reluctant to deviate from the agreed (Foucault, 1995). Therefore workers can be insensitive to changes in the “pressure gradients” discussed above.

This reluctance is based on the imperialistic character of social settings where deviations from the agreed are met with strong social punishment (Foucault, 1995). Humans are very sensitive to this punishment which is rarely very explicit, but often we adjust our actions based on very vague

2) This is the reality built on experiences of the group. Other people, for example safety department, can have other experiences and therefore a different “reality”. No one can claim full supremacy. This is the essence behind the negotiation process developed in this paper. It is not a rhetorical trick to convince workers to work in a certain way, but a genuine negotiation since all levels of the organization have a portion of relevant experience and no one has it all.

indications. Soon we do not even realize these borders of acceptable behaviour since they become an integral part of who we are. For learning from accidents this provides a challenge since it is not sufficient for a single individual to renegotiate practice, but it has to be agreed by a large enough and influential enough group. One example of this was given to me during a discussion with a Swedish fire fighter. He has realized that fire commanders who ride in the front seat of the engine never use seatbelts. He could see no reason for this other than it was seen as a part of professionalism. A commander that used a seatbelt would be seen as a rookie since he (as it disturbingly often is) had not realized the appropriate way to act as a fire commander. Lave and Wenger (1991) go so far as to say that what you learn is not so much about practice as about becoming a practitioner (Brown & Duguid, 1991). This implies that most social settings are extremely conservative and even if one individual receives substantial evidence that something is wrong it will be hard to bring about change since one needs to jeopardize one's status in the group if one challenges the implicitly agreed social contract.

The main point of this chapter has been that the acceptable way of doing things is quite quickly settled in a group based on the perceived relevance of conflicting goals among the most influential individuals in the group. Once settled, the agreed strategies for action are very difficult to influence due to the various forms of social punishment. I believe that changes in routines (written instructions) are not enough to break these impediments for change and therefore an alternative route for change will be discussed in the remainder of this paper. This alternative route is about social renegotiation as a process around which to turn the social reality.

Learning as a renegotiation of practice

The former chapter was descriptive in nature and crudely sketched out how practice is formed in social settings. The available scientific literature in this field is comprehensive and very rewarding. However, since the main goal of our field is intervention one should not stop in the descriptive domain, but allow one self to be more interventive and normative. Therefore the remainder of this paper will focus on how these insights can be used to enhance learning from accidents.

What is clear from the above chapter is that achieving change in a social setting is a very difficult task to undertake and one should not be naïve about the effort needed. One also has to build upon the very same process that is already taking place in practice – social negotiation between competing goals.

One way that has been tested in scientific literature is to simply bring up a subject for negotiation. One example is a study conducted on workers at the former Swedish authority "elverket" (the electricity authority) where the workers were divided into five groups of about 900 people each (Gergersen, Brehmer, & Morén, 1996). The first group was involved in a group discussion circling around safe driver behaviour. The second group received driver training. The third group received a bonus if they were not involved in an accident in the following 2-year period. The fourth group was targeted by an information campaign and the fifth group was a control group. The study clearly showed that the greatest effect was from the group discussions. This is the only comparative study in which group discussions were compared to other possible strategies, but a beneficial effect of group discussions has been found in many other cases (e.g. Lewin, 1947; Misumi, 1982).

I believe that a similar approach can be used for learning from accidents where the accident is used as an impetus for change. In the man-made disaster model (Turner, 1978; Turner & Pidgeon, 1997) accidents are not considered as physical impacts but as a "significant disruption or collapse of the existing cultural beliefs and norms about hazards" (Pidgeon & O'Leary, 2000). If the organization can assist in facilitating a productive renegotiation of practice in the wake of this perceived collapse there are good reasons to believe that practice can be persistently altered. An accident clearly shows the inadequacy of current practice and should therefore be possible to use as a strong theme around which to renegotiate behaviour.

One potential problem for this renegotiation in the wake of an accident is the will to allocate blame (Gephart, 1984; Pidgeon & O'Leary, 2000). There is an obvious risk that the learning develops into a blame game (Boin et al., 2005; Stern, 1997) where the discussion circulates around who did wrong rather than how practice or environment can be changed to reduce the risk of reoccurrence. This will lead to the people involved taking defensive positions and potentially withholding information so as not to be accused of causing the accident (Stern, 1999). For learning, the question of who did wrong is of subordinated interest. The question is rather what one should do to reduce the risk of reoccurrence. One important discussion is therefore how the allocation of blame can be minimized so productive learning can take place. I believe that this can best be achieved through practice – through sessions where the allocation of blame is prohibited.

However, an extensive search into the literature on this topic has not been possible within the scope of this paper so this conclusion should be seen as tentative.

Since renegotiation, per definition and as discussed above, is a social process, one could argue that the renegotiation should take place in groups that are assembled based on the current scientific knowledge about how to achieve the highest level of creativity. However, daily work is also a highly social process (in most organizations) so the problem with renegotiation in other settings than within the already present working groups, what Wenger (1998) calls "Communities of Practice", is the suspicion that the renegotiated procedures will not be used. For the renegotiated practice to really take the step from espoused to used it is of vital importance that each individual knows that the workers that surround them agree on the same working procedures and that he/she does not therefore have to be afraid of jeopardizing her/his status when conducting work in accordance with these new procedures. This has not been tested empirically and should therefore be seen as preliminary, but, drawing on available literature, this group division may be seen as a plausible hypothesis.

One interesting question is whether this renegotiation is already taking place in practice following accidents. That this should be the case in open and fair social environments seems quite plausible, but I have found no studies that focus on this so it would be a very interesting quest to pursue. It could be that practice is renegotiated, but I believe that technical fixes that are developed during these discussions are often not communicated to the people with the formal right to make these changes.

I believe that the process outlined in the following subchapter will serve two purposes. Firstly that it will make the renegotiation of practice more efficient. Not least since it will emphasize that the changing of practice is the responsibility of the skilled and competent people involved in the actual practice rather than outsiders from a specialist department. Besides, fewer changes suggested by insiders will be missed by people who have the formal right to implement these changes.

This chapter has introduced group discussions as a means to renegotiating the assumed model of reality. Real accidents were introduced as a potentially strong impetus to achieve such renegotiations.

Facilitating collaborative learning from accidents

The text up to this point has aimed toward emphasizing the importance of the silently agreed world view (or the socially constructed reality) when it comes to work place practice, and therefore also for safety. It has also been stated that actual accidents can serve as an impetus to challenge the assumptions behind this conception of the world and therefore to renegotiate behaviour. The present chapter will try to present some initial thoughts on how this renegotiation can be achieved in practice. The suggested approach has not been empirically tested, but the working procedures on which the suggested procedure is based is well established and tested (see below). This provides good reasons to believe that the working procedure will indeed be valuable, but, needless to say, this should be tested in future research.

Two working procedures have served as a primary source of inspiration; the After-Action Review (CALL, 1993; Garvin, 2000) and the group discussion technique employed by, for example, the driver behaviour study discussed above (Gergersen et al., 1996; Misumi, 1978, 1982). The After-Action Review has been developed by the U.S. Army to promote learning from both exercises and real battles. The approach has proved itself so valuable that it has spread to, for example, humanitarian relief (Sexton, 2003), wild-fire response (NAFRI, 2003) and major companies (Garvin, 2000). The second source of inspiration was discussed above. The characteristics of these two working procedures are outlined below.

Table 1 – Misumi's group discussion technique and the U.S. Army's After-Action Review. Adopted from Gergersen et al. (1996) and Garvin (2000) respectively.

Group discussion technique	After-Action Review
1. A 60-minute warming up period designed to ease tension among the participants	1. What did we set out to do?
2. Split up into four groups. A 40-minute discussion to identify problems at their work places.	2. What actually happened?
3. A 20-minute meeting in the large group during which the results of step 2 were reported. A list of 10 items was produced.	3. Why did it happen?
4. Each small group discussed which problems they could solve themselves and which problems the company should try to solve	4. What can be done the next time?
5. The results were presented in the large group.	
6. Discussion in small groups about measures and changes in driver behaviour.	

With the inspiration of these well developed working procedures the following process can be suggested. The session can be based either on a single accident in one's own organization or in a similar organization. The session can also be based on a number of accidents that share some characteristics. The selection of events is primarily an issue for management (or safety department), but one should be sensitive to the safety concerns of all levels. This may positively influence the dedication of the participants.

1. A session with a large group is organized, during which the ground rules[3] are discussed. This is followed by a presentation of observable facts concerning the accident (or accidents). The presentation should describe what happened and not why.
2. Split into smaller groups based on existing every day working groups (as discussed above) and discuss the following two open questions: "Why did it happen?" and "How can we prevent it from happening in the future?"
3. The larger group is reassembled and the results are presented.
4. The smaller groups discuss to decide which problems they could solve themselves and which problems other departments should try to solve.
5. Reassemble in the larger group. The results are presented (and documented by facilitators) and the session is ended in a positive spirit.

One potential problem with this working procedure is that it requires substantial resources and therefore it is probably only possible to conduct it a few times per year. However, once people start getting used to these kinds of discussions a simplified discussion could be performed during regular department meetings circling around the three key questions; "What happened?", "Why did it happen?" and "How can we prevent it from happening in the future?"

It is also likely that the process will have very valuable spin-off effects since it becomes evident that safe working behavior is primarily one's own responsibility. Of course actions may need to be taken by the organization, but it is everyone's responsibility to make the organization aware of the changes identified as essential for safety. It is also possible that employees will improve in addressing and discussing smaller mishaps that occur on a day to day basis.

It is worth noting that even if most of the terminology used in this paper is based on industrial settings, there is no reason to believe that the

3) The focus is on what has happened, not who did it. The aim is not blame allocation but learning to prevent it from happening again and all personal attacks are forbidden.

approach should only be applicable in such settings. It is probably of equal value in a school, elderly home or an amusement park.

Conclusions and future work

This paper emphasizes the relevance of informal processes on formation of practice and therefore also for safety. The importance of traditional accident investigation is not denied, but the notion is stressed that the role of outsiders in forming workplace practice is generally overemphasized.

It is argued as an additional challenge for learning from accidents to facilitate the process of challenging the silently agreed models of reality in the wake of an accident. Some initial thoughts on such a development are also presented.

However, much work is still needed. As mentioned above, much descriptive scientific literature on practice formation is available (e.g. Giddens, 1984; Orr, 1996) and should be analyzed from a safety perspective. These accounts are very compatible with social constructivism so insights from general social constructivism should also be well suited.

For the future I would recommend a research program influenced by action research (Lewin, 1946) and ethnology. Where a first round of observation can be followed by an intervention (maybe in the form presented in this paper) which in turn can be followed by another round of observation. I believe that this will not only provide the most practically suited working procedure, but also the greatest insights for understanding the social construction of reality.

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Kenneth Pettersen

Biography

Role in the Project

Writer

Work/Studies today

I am a research fellow at the University of Stavanger and started my PhD-studies in risk management and societal safety at the university in 2003.

Background

Born 1977 in Oslo, Norway. I have an undergraduate degree in social pedagogics from Bergen University and a graduate degree in risk management and societal safety from the University of Stavanger

Contribution to this project

I have been synthesising some perspectives, both philosophical, theoretical and empirical, regarding the development of accidents and accident prevention in socio-technical systems

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The relationship between social reality and the physical

– A causal nexus for operational safety and vulnerability

Introduction

Understanding social precursors to safety and vulnerability in socio-technical systems is, viewed in an historical perspective, a recent development. Such a perspective was first introduced in 1976, when Barry Turner published his work on Man-Made Disasters. Turner argued, grounded in 84 accident reports, that social and cultural aspects are causal mechanisms in the development of accidents. Since his work was first published, there has been a growing body of research concerned with accident development and prevention in socio-technical systems based on a perspective that accidents are man-made.

The partial core meltdown of reactor 2 at Three Mile Island in 1979 (La Porte 1982), the disastrous release of gas from a Union Carbide pesticide factory in Bhopal India in 1984 (Shrivastava 1987) and the destruction of the space shuttle Challenger in 1986 (Vaughan 1996) are accidents where social and cultural aspects have been analysed for developing knowledge about safety and vulnerability in socio-technical systems. In addition, research has been conducted in systems that have a record for being safe. Notable has been the work conducted by the High Reliability School (Roberts 1993). High Reliability Organisations Theory argues that there exist organisations that have the ability to anticipate and deal with failures. In the words of Gene Rochlin (1999), what was found in the initial studies of high reliability organisations, such as naval aircraft carriers, air traffic management organisations and electric power-grid operations, was *"(…) organisations that showed a positive engagement with the construction of operational safety that extends beyond controlling or mitigation of untoward or unexpected events and seeks instead to anticipate and plan for them"* (Rochlin 1999 p.1549).

One element that connects studies that include social factors in the analysis of accidents and high reliability is accounts of a relationship between the ideas, meanings and interpretations of a social group (i.e. social reality), human actions and the objects and consequences of the physical world. One may say that in socio-technical systems there is a causal relationship between social realities and what is and comes to be physical facts (i.e. objects, events and consequences). In this paper I argue that this relationship is a causal nexus for understanding the human role in socio-technical systems. I consider how vulnerability and safety (i.e. the establishment of risk levels to be tolerated and enforced) develop within the social reality of a socio-technical system based on social constructionist philosophy and discuss the relationship above based on this perspective. The relevance of the causal relationship for understanding operational safety and vulnerability is elaborated on by introducing empirical examples from a qualitative interpretive study conducted in a Norwegian aviation line maintenance department.

The social construction of safety and vulnerability

When Barry Turner (1978) published his Man-Made Disaster theory three decades ago he was perhaps the first to introduce elements of philosophy of social construction to the understanding of how vulnerability develops in socio-technical systems. In particular, Turner's main causal mechanism in explaining the development of accidents was his idea of "failures of foresight" (Vaughan in Turner and Pidgeon 1997). Failures of foresight are caused by the characteristics of social reality, and results in blindness towards certain events, facts or developments that will or can cause accidents. Grounded in 84 accident reports, Turner grouped failures of foresight into four categories (Turner and Pidgeon 1997, p.85): The events, facts or developments in question (e.g. what is really happening) may be unnoticed: 1) because of erroneous assumptions on the part of those who might have noticed them; 2) because of information handling difficulties in complex situations; 3) because of a cultural lag in existing precautions; and 4) because those concerned were reluctant to take notice of events which signalled a disastrous outcome.

Related to Turners theory, Andrew Hopkins (1999 p.141) has formulated a very relevant question that summarises Turners categories above: *"What stops people from acquiring and using appropriate advance warning information so that large-scale accidents and disasters are prevented?"*

Although the question above may look short and simple, it concerns some fundamental issues regarding the understanding of vulnerability and safety in socio-technical systems. Firstly, Hopkins question concerns how people know about the world ("What stops people from acquiring and using appropriate advance warning information?") How do we know what is safe or vulnerable and what constrains us from knowing this? Secondly, Hopkins question concerns in what way do or do not our actions based on our knowledge influence the physical world ("that large-scale accidents and disasters are prevented"). Reformulated in this way Hopkins question concerns fundamental questions within social science. What is reality? How do we know about this reality? And in social systems, where intentionality exists, what is the role of human agency?

The philosophy of social construction

Social constructionist theory explains social reality as developed through individual's relation to a specific social and historical context (Berger & Luckmann 1966). The meaning humans ascribe to actions, events and situations are thus intrinsically dependent of social context. Meaning, what individual agents cognitively construe as meaningful and true (i.e. social reality) is formed by among other the cultural heritage, for example as in the case below the professional culture of maintenance technicians. Furthermore, in a social constructionist social model social structures of actions are not understood as existing independently of individual human construal. Social structures are created by individual human activity. Yet, once created they may take on an existence independent of individuals. Through social construction human subjectivity can become embodied in social products, for example tools, parts, procedures, practices and regulatory systems, existing alien to the individual. These social facts, existing objective to human agents, in turn construct individual meaning and interpretation. The theory is thus dialectic, in that individuals construct social systems that again construct individuals and so on in a continuous relationship.

If we interpret safety as a construct of social reality, our knowledge about what is safe or vulnerable is dependant on the socially developed and agreed upon (e.g. normative risk levels established based on social reality). Thus, knowledge and assumptions about safety are not based on an independently validated rational process. Our knowledge is socially contingent, essentially dependant on social context.

To understand this, it is important to add that the social reality concept as used by Berger and Luckmann (1966), including the claim of its social relativity, is constrained within the context of sociology and does not concern the philosophical quest for the ultimate status of reality. Berger and Luckmann (1966) do not claim for any form of universal social constructionism. However, this does not mean that there is no relationship between social constructs and physical consequences. The constructed reality of social groups is very real for the participants that are in them, and the actions we take based on our knowledge have a physical dimension both in their performance and in their consequences. Meaning, actions and consequences of our actions do exist independent of interpretations of them. This is an essential distinction that from my point of view is important for defining the explanatory power of constructionist theory and clearly separates it from the developments within constructivist philosophy aimed at reducing all aspects of reality to social constructs.

Reducing reality to a social construct ends up being tautological whit no real explanatory value. As Hacking (1999 p.24) writes; *"What would be the point of arguing that danger, or the woman refugee, is socially constructed, if you thought that everything is socially constructed?"* This is also supported by the fact that it is very hard to find anyone who argues for universal constructionism. According to Hacking (1999) universal constructionism is descended from linguistic idealism where only that what is talked or written about exists. Most accounts of constructionism are not based on this universalism; they are instead more specific and make claims that are context dependant. Writing of universal constructionism does however not mean that there are no links between physical states and our knowledge about them. On the contrary, as stated above, the actions that are taken based on what we know (i.e. social reality) have a physical dimension. In fact, I argue this is an essential causal relationship we must recognize if we are to avoid failures of foresight.

I have argued that knowledge of safety and vulnerability are socially contingent. Moreover, society in general is not homogeneous. Based on this, what people understand as safe will vary between both societies on the macro level and social groups on the micro level. Therefore, in a socio-technical system there may be numerous social groups, from government, politicians and regulators on the top levels of the system, down through company leaderships to management and operational personnel at the sharp end, that operate depending on several social realties. Together these social groups constitute the social system involved in the continuous development of a socio-technical systems operational safety. However, what these different groups interpret and understand as vulnerable and safe and thus also how they act may be diverse. Nevertheless, for an institutionalised social group their social reality is often taken for granted and the “trueness” of it is not regularly questioned within the group (Berger and Luckmann 1966).

Uncertainty and imperfect knowledge are characteristics of social reality

The implication of the above is that there exists a world independent of our constructions of it. However, in socio-technical systems there are social “worlds” of meanings and ideas that have causal influence on the human actions that interact with physical objects (Hacking 1999). Take as an example a routine flight with a Boeing 737. If we try to model what really happens during such an activity there are objects that exist objectively. For example, the aircraft and its technical systems are physical facts. Also the aircrafts physical movement from one position on our planet to another is a physical fact. Simultaneously, there is a social system involved and thus social realities that influence the actions of those involved in the object of flight. For example, during a routine flight social reality encompasses both meaning and interpretations of organisation of work within a social systems and the way it is governed and regulated.

Now consider the topic of safety. Is flight safety a physical object or is it a social construct? My understanding is that it is both. Safety has a physical dimension in human actions and consequences just as failure has. That the maintenance technicians repair a part, that the cabin crew shut all the doors and the pilots steer the aircraft are all physical facts that could be part of a flight. But flight safety is also a social construction. The appropriate risk levels to be tolerated and enforced and how human agents involved interpret that operational safety is achieved are social constructs. Moreover, there would be no flight safety as it comes to exist at all without the institution of civil aviation and the rules and practices of people. In fact there would be no flight at all because the aircraft design itself is also a social construction. However, it is also undoubtedly physical.

Karl Weick is a scholar who has brought elements of a social constructionist philosophy into safety science and who has showed appreciation of

Barry Turners theory of Man-Made Disasters. In a quote from a special issue of Journal of Contingencies and Crisis Management (1998, Vol. 6(2) p.72) Weick wisely notes how Turner gives insight into the social pre-conditions to accidents.

Accidents *"(…) often seem to be the work of ontologically confused social realists in organizations who are beset with perceptual rigidities, informational ambiguities, dis-regard of rules, susceptibility to decoys, over–confidence, hubris and mis-placed concreteness"* (Ibid).

In this quote Karl Weick sums up the essence of Turners (1978) argument of how accidents develop through incubation. Failures of foresight hibernate within one or several different social groups in a socio-technical system. Let's elaborate on the quote above and relate it to the philosophy of social construction.

Because of the nature of the social processes (i.e. social construction) for developing knowledge we have to manage our actions based on knowledge, including constructions of safety, which is ontologically insecure. Thus there is essentially no direct match between what socially is established as true and what actually has, is and will happen. As a consequence no secure truth about what constitutes safety and vulnerability does exist to guide every-day operations of work. Even in a system such as civil aviation, which has developed very efficient operations, ontologically confusion is a contingent possibility. The consequence is that operational safety is achieved under conditions of uncertainty. Here I am not referring to probabilistic uncertainty *"(…) where the structures of a problem is well-defined and only the value of the parameters within the structure are unknown"* (Pidgeon 1998, p.98). What I am referring to is what Pidgeon labels as a *"(…) deeper form of systemic uncertainty where the very structure of a model or world-view is incomplete or open to doubt in critical respects"* (Ibid). This uncertainty, the incompleteness of our knowledge, is what prerequisites failures of foresight and it is this uncertainty that must be acknowledged and managed if we are to achieve safety.

Incompleteness of knowledge is evident if we study accidents in hindsight. Every accident investigator, in fact most people, can with considerable ease find some slips or mishaps prior to an accident if they are given enough information about the accident in hindsight. During foresight however, if we take the argumentation above into account, incompleteness is not only a characteristic of social reality existing prior to accidents, it is a characteristic of social reality in general. Related to the latter, in a recent research project I have studied how an aircraft maintenance organisation manage uncertainty and explain some characteristics of the social system of aircraft maintenance relevant (Pettersen 2006, Pettersen & Aase 2006).

Social constructs and consequences for operational safety in civil aviation

The outline of social construction theory above focuses on the role of the social in the development of safety and vulnerability in socio-technical systems. I have argued that the operational safety of technology systems is dependant on the social reality of social groups involved and how they through their actions interact with physical objects and produce events based on what can be conceptualised as social constructions. This causal relationship is symmetrical in the sense that it is equally relevant for explaining both safety and vulnerability.

As part of research for my PhD dissertation, I have conducted a qualitative interpretive study in an aircraft line maintenance department. Below I argue for the relevance of the causal relationship described above by describe elements of the social reality of a line maintenance department and give some examples of how they conduct their work in the civil aviation system through. I found that their efficient, both productive and safe, way of working was related to how they dealt with uncertainty.

Line maintenance technicians perform a central role in the social system involved in assuring the operational safety of civil aviation (Pettersen 2006). In this case, their work included technical checks and maintenance on aircraft between flights and during aircrafts scheduled inoperative periods. In addition to checks and maintenance, the technicians were involved in diagnosis of symptoms or technical faults that occurred during flight operations.

Acknowledging systemic uncertainty

The civil aviation system is both technically and socially complex. In the study I found that this contributed to a high degree of uncertainty and continuously challenged the technicians' knowledge about objects, events and consequences. For example, when the line technicians worked to diagnose and solve certain technical problems, the aircrafts´ technical systems could be so complex that uncertainty was inherent in the system. For example, uncertainty was described associated with faults that were intermittent, faults that became manifest only when an aircraft is airborne or even new categories of faults resulting from interaction between technical subsystems or the technologies´ interaction with the environment. However, instead of ignoring what they did not know and possibly developing failures of foresight, the technicians were continuously challenging their uncertainty. They were constantly revising their knowledge and their degree of certainty about it (Dekker 2006). Formulated in another way, their social construction of safety and vulnerability was not stable but dynamic and open to change. This dynamic was also evident in how they valued, and practiced according to, formal descriptions of work.

The technicians´ understanding of the socio-technical system in which they worked and interacted was anchored in an extensive net of detailed procedures, rules, standards and regulations that they had to comply to. All technicians I talked to emphasised the importance and necessity of formal descriptions of work and regulations as a knowledge source and guide for work practice. Thus, formal descriptions of work were fundamental for the operations of the system. However, most of the technicians emphasised that during specific work tasks, procedures and regulations could be poorly descriptive, excessively detailed and in some cases also wrong. In addition, many of the formal procedures they had to follow, such as paperwork for ordering of parts and making them serviceable, was time-consuming and distracting. This contradiction in how they valued formal descriptions of work reflects the fundamental insecurity they had in their social construction of safety and vulnerability. More precisely, the technicians´ assumption that their knowledge about physical objects and events was permanently imperfect did also encompass sensitivity towards formal knowledge sources.

Relevant for the above, Rochlin (1999) has remarked that safety in organisations cannot be captured empirically and described solely by the use of positivistic terms. Formal descriptions of work such as policies, rules and procedures will never capture the processes by which safety is created and maintained. Neither will sets of human and organisational performance categories used to infer deductively about empirical observations of safety. Slovic (1992 p.119) elaborates on the concept of safety as something that does not exist in the world independent of our minds and our culture that is ready to be measured. It is a concept constructed by humans, and therefore more easily judged than defined.

Local adaptations of practice and the relevance of informal knowledge

Local adaptations in organising and practice were made by the line technicians during specific maintenance tasks depending on how they understood the situation. Maintenance tasks varied depending on among other the nature of the technical problem, the operational status of the aircraft, the availability of tools and parts, and the availability of personnel. When making local adaptations, the technicians made extensive use of formal knowledge sources. However, practicality was often a factor when the organisation constantly had to address the challenges of different task situations. As a consequence, the organisation made use of informal knowledge, which was supported by flexibility in the organisations structure. Depending on the task at hand, predominance could be given to operational personnel with first-hand information about operational conditions and technicians with specialised skills and experience. Thus, the organisation had a flexible adaptive structure where personnel had the opportunity to be sensitive towards how they could reconfigure to address challenges better (Roberts and Tadmore 2002).

What supported and made flexible adaptations possible was not a "cowboy" culture among the technicians, giving way to bald-headed and risk taking individuals. On the contrary, the technicians repeatedly emphasised level-headedness and humbleness towards one owns skills and knowledge as a desirable trait among colleagues. Technicians with many years of experience or who had demonstrated skills in certain technical domains were treated with respect and promoted by colleagues. Only technicians with specialised skills within the relevant area of expertise or experience related to the specific task were trusted as informal knowledge sources.

Relevance of organisational structure and decision-making hierarchies

As mentioned above there was flexibility in the structure of the line maintenance organisation. Moreover, the line technicians were organised in a way that minimized hierarchy in decision-making processes. The line department was part of a larger technical organisation that included a large heavy maintenance base, a component repair shop and an engineering department. In relation to the account of local adaptations given above, when a technical problem was outside what a line technician perceived as his boundary of expertise he could search the organisation for knowledge and specialised skill. This was possible due to the structure of the organisation. The organisation was "flat" with a reasonably small administration (65 individuals) and a large operational base (245 individuals). In addition there were no structural "trails" of hierarchy the technicians had to follow to get access to skilled colleagues in other parts of the organisation. Together with a shared culture of supporting the operations of the line department, this meant that line technicians could contact personnel with a specific competence or knowledge directly no matter where in the organisation the person in question formally belonged. It was legitimate practice to bring people over from other departments to get their perspective and make use of their knowledge and skills. This can perhaps be characterised as "garbage can" processes and supports assumptions made by Karl Weick (1998) that flat structures where order and power is moderated might heighten organisations ability to discover and correct failures before they incubate into disaster.

Following Weick's (1998) reasoning, which I find is similar to Turners (1976) empirical accounts of failures of foresight, it could be that the common assumption that "garbage can" processes is a danger in high-hazard systems is over-emphasised. In fact, as the empirical case above illustrates, organisations with processes that are comparable to the garbage-can model can have fewer pathways for developing failures of foresight. These organisations may not only be less prone to failures created by hierarchy, they may also have, through their flat structures where order and power is moderated, a heightened ability to discover and correct failures before they incubate into disaster (Weick, Sutcliffe and Obstfeld 1999).

The challenge of socially distributed information

In connection with the philosophy of social construction above, I state that the social structure of socio-technical systems seldom consists of one homogeneous social group. More often, the social structure is heterogeneous consisting of numerous groups with different configurations and interpretations of the world. Although there are many formal knowledge system for gathering and distributing information in aircraft maintenance these systems were seldom functioning perfectly. Perfectly meaning functioning in the way the system rationality intended them to. One main reason for this is that the systems were in operation partly social systems. Therefore, knowledge processes did not function independently of social constrains. Within the aircraft technicians social system the status of some information was regulated, among other due to information overload, based on social negotiation. In addition information was distributed based on power relations between actors and the existence and availability of communication channels. The status of and distribution of information must therefore be understood in relation to human and social constraints.

Social constraints may result in situations where people have diverse, non-overlapping, pieces of information about a problem and subsequently may infer differently related to what is happening. This may result in a problem becoming framed by systemic uncertainty as described above. Turner categorises this as one of the aspects that causes failures of foresight (Turner and Pidgeon 1997). A consequence of these types of failures in aircraft maintenance can be ignorance of technical problems leading to safety events or unawareness of maintenance actions left to develop in unexpected ways

"Each person has partial information that is incomprehensible because crucial pieces are missing. Technology is less of a problem than is the way people are organized. Given the tendency of people to satisfice and make do with what information they have, it is possible that accidents happen because information is incomplete [and] the gaps are smoothed over in ways that sustain the illusion of safety (Weick 1998 p.74).

Distributed information was a challenge the line technicians had to deal with because communication was often constrained. However, in relation to specific maintenance tasks I observed that the use of small operational units and decentralisation of decision making power to operations minimised problems related to distribution of information.

On the other hand, what increased the possibility of communication difficulties and the likelihood of failures of foresight was large scale organisational changes in the technical organisation (Pettersen and Aase 2006). The organisational changes involved downsizing, changes in goals, new responsibilities and roles for the technicians, and changes in routines and procedures. In these change processes the entire socio-technical system was involved and affected. Information was spread out and distributed on all levels of the system, among other resulting in information handling difficulties related to implementation of changes that affected the technicians´ practice. Turner and Pidgeon (1997) state that large-scale organisational task, such as these change processes, increase the likelihood of communication failures because *"(…) each organizational unit or sub-unit will have developed its own distinctive sub-culture and its own version of rationality, which may give rise to erroneous assumptions about the portion of the problem that is being handled by other units. Again, the more prolonged, the more complex, the more vague, the more hasty and the more large-scale the task, the more likelihood there is of information-handling difficulties arising* (Turner and Pidgeon 1997 p.87).

Consider the following example; technicians usually replaced aircraft tires following an established practice of the line department. This practice was efficient and involved organising the tires in the hangar categorised after aircraft models. This made it possible to go to the tire depot and pick up a tire following categorisation, knowing they had the correct tire for the specific type of aircraft they where working on. After large-scale changes in the organisation, involving a new delivery system for all aircraft parts including tires, the routine for delivering tires changed resulting in a new way of marking tires delivered to the hangar. In one specific case that followed after these changes a technician replaced an aircraft tire with the wrong tire model and released the aircraft for operations. Although the technician followed the established practice that had always functioned prior to the changes his rationality did no longer function in relation to the changes introduced by other parts of the system. He should, following the changes, now have checked the specific part number on the tire and not assumed, as would have been correct before, that the tire was correct because of its place in the hangar tire rack. This incident did not have serious consequences for the operational safety of the aircraft and the fault was quickly discovered and corrected by the technician. However, it illustrates how the social reality and subsequent actions on one level or part of the social system, including the distribution of information, interact and are constraints for actions performed on other levels. As this example illustrates, this can have consequences for operational safety and vulnerability.

Concluding discussion

In this paper I have focused on the relationship between social reality, human actions and what is and comes to be physical facts (e.g. objects, events and consequences). The reason for this focal point is its relevance for understanding how operational safety and vulnerability develop in socio-technical systems. However, explaining the relationship presupposes a model of the social system involved. Here I have applied a social constructionist model based on Berger and Luckmann (1966) that explains how social systems are constructions of its individual agents and how human knowledge, the meaning humans ascribe to actions, events and situations are intrinsically dependent of social context. I have attempted to show the relevance of this model for understanding the relationship between the social and the physical in socio-technical systems building on the work of Turner (1978) and Weick (1998) and the claim that uncertainty of knowledge is intrinsic of any social reality.

Reflecting on interactions between social reality and the physical starting from Turners (1976) conceptualization of "failures of foresight" I argue that it is characteristic of any socio-technical system that ignorance of what is happening can lead to the development of accidents. The reason for this is the bounded rationality that develops in social groups as a consequence of the social process of knowledge construction. This process constrains people's range of foresight, by limiting the precautions they take, the range of unwanted consequences they envision and the range of information they seek. I emphasize that uncertainty and imperfect knowledge are characteristics of social reality and that it is this uncertainty that must be acknowledged and managed if we are to interact with the physical world so that safety is achieved.

In the empirical case from civil aviation I approached the relationship between the social, maintenance actions and the aircraft technology based on some accounts of how line technicians manage uncertainty. I argue that through revisions of knowledge (i.e. processes of social construction) concerning safety and vulnerability, which is enabled by a cultural acknowledgement of imperfection, aircraft line technicians prevent the development of failures of foresight and contributed to the operational safety of the aviation system. In the line maintenance department I found that ignorance of safety concerns were contested based on an awareness of imperfection in both knowledge and practice and also supported by a strong cultural predominance to achieving safety in comparison with achieving other goals, such as productivity. Institutionalisation of the *"(…) value of slowing things down to enhance reliability and address all safety concerns"* (Roberts and Tadmore 2002) guided the technicians in their agency and gave legitimacy to the creation of extended performance spaces (i.e. timeframes). In the words of passengers these performance spaces often fall under the category "delays due to technical reasons". In the words of operational safety, these performance spaces are essential for avoiding the pitfalls of time-constrained situations and create opportunities to revise ones knowledge of what is really happening.

However, the characteristics of the social system outlined here, which supported knowledge management and gave leverage to the individual intentionality of the maintenance technicians, are not an exhaustive account of the social system involved. Among other, I show how social constraints in the system resulted in challenges to distribution of information. I find that it is difficult to describe and explain the role of some of these constraints based on a social construction model because they are not a product of any social construction process in the maintenance organisation. They do however appear to have causal influence on the actions of the maintenance technicians and also existing in a causal relationship producing outcome together with local maintenance actions. As the aircraft tire example above indicates, actions on one level or part of the social system interact and are constraints for actions performed on other levels.

Despite of this inconclusiveness in accounting for different causal influences, I find that applying social constructionist theory is constructive for understand the social system, because it involves how actors themselves experience and explain the system. In addition, social constructionism proposes a model of the causal role of this knowledge in the development of a distinct social reality and the causation of human action. Social construction theory also gives some explanations relevant for understanding the relationship between social reality and physical facts, which seems to be vital for understanding the human role in socio-technical systems. Among other, by accounting for how social context and cultural heritage assure stability of human actions over time. Furthermore, social construction theory enables an explanation of the individual readjustments of meaning and knowledge that in some instances seem to mediate the social order of the system. Accordingly, social construction theory supports the explanation of actions produced by social adaptations under the influence of informal knowledge, which are found to be significant for managing uncertainty in aircraft line maintenance operations.

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Elena Beauchamp

Biography

Role in the Project:

Writer

Work/ Studies today

I am a PhD researcher at Delft University of Technology (The Netherlands), Faculty of Technology, Policy and Management, Safety Science Group (Promoter: Professor Andrew R. Hale). Project work: HILAS – Human Integration into the Lifecycle of Aviation Systems.

Background:

After graduating as an engineer-designer of electronic equipment for aircraft, I worked for an aviation company in its Safety & Reliability department. Having a great interest in the application of knowledge of technologies in a broad range of societal issues, in the analysis of social dynamics and providing the synergy between academic research and public policy, I returned to university and did my post-graduate study in Sociology and Policy Analysis, successfully defending my doctoral thesis on Mathematical Modelling and Simulation for Forecasting and Decision-Making as applied to Policy Analysis Issues (Moscow, 1999). Since then, I have carried out several years of academic research and teaching in Russia, Germany and France. My main research interests are managing complex systems, decision making, risk evaluation and resilience; modelling and the forecasting of social dynamics, as well as social and human development. I am also interested in philosophical issues in management, particularly the link between ethics, aesthetics and decision-making. In 2005 I joined the Safety Science Group at TU Delft with a focus on Organisational Learning, Integrated Risk Assessment and Risk based Decision-Making in Aviation Systems. Outside my professional life I have many interests, including travel, reading, cooking and gardening. I also paint and play the piano, and share my passion for art and classical music with my husband, a professional opera director.

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Learning for Change: a Search for a Holistic Approach

'Our task must be to free ourselves from this prison by widening our circles of compassion to embrace all living creatures and the whole of nature in its beauty.'

- Albert Einstein

Social Dynamics and Planning: Rational or Humanitarian?

Nowadays social dynamics and social development have acquired a key significance in considering the concept of sustainable development. Sustainable development is an attempt to avoid interruption to, or a malfunctioning of, the social system. However, such a concept presupposes a change to the managerial approach as well as to priorities, values and demands at an individual and organisational level. The role of strategic management in considering the immediate and future impact of company policy is a long-term task. Especially important is the evaluation of policy with regard to the well-being of future generations. But as Alker and McDonald (2003, p.172) demonstrate, progress in planning and development over the last two decades has resulted in unsustainable development in many urban areas.

Despite the fact that 'development plans', or normative planning oriented to economic welfare, may produce an unsustainable lifestyle, political realities almost always give primacy to the economy. Thus the environment, indeed society as a whole, has become a resource to be exploited. (Giddings, Hopwood and O'Brien, 2002).

From the belief in progress and rationality which prevails in the social sciences, it follows 'a priori' that people are capable of influencing the world in which they live, and of changing it according to their wishes; and that progress is the natural state of social systems. However, from the point of view of self-organizing systems theory, the logic of permanent progress is not necessarily evident. In other words, the probability of social progress does not mean that it is inevitable.

If uncertainty is characteristic of social development then the notion that society regulates everything likewise in mechanistic determinist terms becomes unrealistic. Furthermore, social systems are capable of adapting to regulating impacts, and thus the response of a system to regulating impacts has a non-linear character.

Post-normal science considers a social system as a Self-Organizing Holarchic Open System (SOHO) (Kay et. al., 1999; Lane and Oliva, 1998), where the prevailing explanations in terms of linear causality and stochastic properties are inappropriate. Multiple possible pathways for development need to be considered. In policy analysis, response to the inadequacies of logical positivism is known as "critical multiplism" (Cook, 1985).

Traditional disciplinary reductionism in science and in experts' predictions has limited applicability in order to obtain adequate descriptions of the dynamics of SOHO systems. A search for preferences concerning the attributes of SOHO systems in "increasing the range of human choices" (Anand and Sen, 2000) leads to the introduction of both adaptive and participatory principles of management.

The adaptive principle of management is considered as a continuous process of learning, revising, resolving tradeoffs and planning to adapt to unfolding situations (Kay et. al., 1999).

The participatory principle of management indicates a transition from government to governance on the basis of learning values, beliefs etc.; it is considered as a never-ending process, which should deal with the accumulation of insights into systemic causes and effects, by anyone with an interest in decisions or issues (Meppem and Gill, 1998). The participatory approach is required in order to find a reasonable reconciliation of conflicting interests. (Martinez-Alier, 1995).

The following trends apply to the most important principles of community strategies (Williams, 2002): co-ordination, a long-term vision for the area, adaptation of holistic and integrative approaches and the empowerment of people and communities to articulate their needs, aspirations and priorities.

A post-modern strategic model assumes the inclusion of rationality. However, this is not simply a matter of finding an adequate formal representation of problems through technical procedures (for example, mathematical modelling), but is also concerned with finding an adequate conceptual representation of problems, which requires self-conscious and critical choices between competing world-views, ideologies, and myths

(Dunn, 1994). Consequently, the role of policy is not the regulation of human behaviour, but the "generation of the facilitating structures to support individuals in putting their convictions into practice" (Dodds, 1997).

Sustainability should aim at systems which "survive" change, i.e. which maintain a continuous identity, even though their states may change. (Heylighen, 1991; Maturana and Varela, 1980). According to the law of requisite variety, a large variety of actions is more adaptive than a smaller one. Therefore, in order to survive (development without destruction) a system has to allow for an increasing "degree of freedom" (Turchin, 1977), or diversity at the lower level. This means that in the management process a voluntary heterogenetisation should replace aggregating information. This should be a new basis for the rational procedure of reasoning with a focus on meaning.

A large variety cannot be described in terms of bounded rationality, but rather in terms of meta-rationality. Understanding meta-rationality as multiple forms of reasoning, systematically represented, is not new. This term has appeared in relation to complex political decision-making and to the field of policy analysis. We analyse the process of the evolution of rationality from mono-rational forms to meta-rational in a search for an appropriate approach to learning as a contributing factor for system survival or resilience, and we propose to extend the term of meta-rationality, arguing that meta-rationality is more than a simple combination of mono-rationalities. Meta-rationality proposes a mechanism for overcoming the separation between the rational aspects of decision-making (reasoning in itself) and the emotional aspects (values evaluation, i.e. interpretations), which allow for a transition from "pure reasoning" towards "interpretive reasoning" (Favereau, 2001).

Strategy, therefore, becomes the task: how to provide dynamic stability and at the same time to allow a variety of changes in order to increase the adaptive capacity of any system. People's diverse and often competitive aspirations, values and goals are to have a place in natural evolution as a basis for multiple possibilities, while the common goals of social development are achievable through co-ordination and consensus, rather than competition. Strategy and a theory of values (ethics) are both concerned with well-founded actions: in terms of strategy we formulate the question «where are we going?», and in terms of ethics «why are we going there?».

Human systems, like natural systems (but unlike technical systems), are adaptive. Thus the initial purpose(s) of a system and/ or the intensity of purpose can change as well. The decision process helps to evaluate the effectiveness of a plurality of goals in such cases. The core of a decision process is how to manage, i.e. how to modify the system and to provide dynamic stability.

We need an analytical view of the world to help shape the future, rather than adjust to it. We need an alternative to formal rational reasoning. This means that strategizing and decision-making processes which are not rational in themselves increase our capacity to be "rational", i.e. to think systematically "what for?" Following Heylighen (1991), the fact that a controlled sequence of combinations can be generated and its consequences explored might be defined as rationality.

Acts are considered rational if they successfully fulfil their goals (operational appropriateness) and do not obstruct other actors (ethical acceptability) (Jokinen, 1995). This explains why rationality leads to the more general context of cultural values and social norms. The separation of facts from values is made not at the lower level but at the "rational", i.e. management level. Thus, rationality is an instrumental concept, a sign of the actor's competence to plan, co-ordinate and choose actions, so that such behaviour looks competent and fulfils the goals which motivate action.

We argue that there is a development of system theory concerning devi-

Table 1. Approaching Meta-Rationality

Place of information in regulatory process	Correlation between rationality and coordination	Human actors	Managerial approach	Decision concept	Decision tools
Absolute/ unbounded rationality	Individualism; separation of rationality from coordination	Uniform	Normative	Standard decision theory	Optimisation; 'hard' OR[1]
Substantive/ bounded rationality	Atomised society: pseudocompromise	Uniform	Descriptive incremental	Extended decision theory	Games; cognitive mapping 'soft' OR
Procedural/ bounded rationality	Compromise in search of meaning	Heterogeneous	Cognitive	Non standard decision theory	AI[2]; MCDA[3]
Meta-rationality/ Complex Rationality	Strong correlation; Search of consensus	Heterogeneous	Interpretive	Qualitative decision theory	To be resolved

OR[1] - Operational Research;
AI[2] - Artificial Intelligence;
MCDA[3] - Multi-Criteria Decision Analysis

ations from "cause-consequences" rationality, including them in the process of planning. Such deviations underline the transition from rational to meta-rational (see Table 1).

In practice there is an essential gap between descriptive models of political decisions and normative models of economics where traditional use is made of "Costs – Profit" methods. These methods cannot be applied to decision-making in public policy to resolve social issues because:

- They are multi-faceted, and thus cannot be investigated by normative models of economic theory in decision-making;
- They are multi-actor, i.e. the decision-making process involves many people with personal values and objectives which may conflict with the common goal.

This is why game theory or linear programming results in decisions which are generally acceptable, but optimal for no one.

To emphasise optimisation seems insufficient in the light of sustainability, because the main principle of optimisation focuses on one or several variables, excluding others from consideration. On the other hand a decision process in the context of sustainable development has to strive for the reconciliation of diverse interests, and the consideration of the "ecology" of the problem (see Table 2).

Table 2. Development of decisional approach: from goal-achieving model to goal-formulating model of management.

Character of model	Goal-achieving model of management Model " Top-Bottom "	Goal-formulating model of management Model "Bottom-Up"
Criterion of effectiveness	Achievement of Goal. (Strictly determined system structure)	Achievement of consensus with regard to feedback "Goal–Consequences" (Flexible system structure)
Nature of Decision	Decision=Act (of a choice of optimal variant).	Decision=Process (of comparison and choice of models with verification, correction of feedback Goal –Consequences)
Basis for Evaluation	Multi-attribute Utility Max Profit/ Min Costs	Multi-attribute Value Balance/ Harmonisation of local priorities
Focus	Unification	Voluntary heterogenetisation and Synthesis

The need for reconciliation of diverse interests exists in many situations. For example, designers usually use methods, methodologies and tools to develop specific solutions, representing local optima (Tormey et al., 2003). These specific solutions then need to be combined to create an overall solution and global optima at each level of abstraction of the design process. The combination of such solutions can create conflicts, both real and imagined. Therefore, methodologies and tools are required to support the transformation of 'distributed-based' solutions to a 'consensus-based' solution space, or a set of global optima, at each level of abstraction in the design process.

Learning from Diversity: Expanding Design Perspectives

An aviation system is a complex multi-actor system with an inter-organizational network. When different functional groups are affiliated to multiple organizations, communication is complex due to relatively high cognitive and cultural differences, geographic distances, diverging interests, and manifold interdependent relationships (Hauptman and Hirji, 1999). Therefore, the design process requires methods and tools which support both the building of consensus, and the learning processes of the various development and user groups involved in new product development. By 'diversity' we mean a variety of processes and products emerging from different configurations of stakeholders who have different objectives, knowledge, experience and authority. The potential question is how to facilitate learning processes and to transform knowledge throughout the Life Cycle (LC) between partners with divergent professional backgrounds.

The expected outcomes of Organisational Learning (OL) will be a new understanding, leading to changed practices/ innovative practices. This may refer to changes in policy, in program design or standards, in structures and procedures, or in interpersonal interactions etc.

Much of our thinking and behaviour is rooted in habits and routines, in deeply implicit mental models of how the world works, and in well-concealed assumptions and prejudices (i.e. pre-judgments). On the other hand, our habits, assumptions and mental models impose uniformity and simplification on the complexity and variety of events and experiences, thereby obscuring and negating 'differences'. Learning, therefore, involves both – better reflection and analysis for 'institutional memory', and the ability to 'suspend' our acquired knowledge. The suspension of acquired knowledge is required to provide the space to recognize 'differences', and to introduce caution in transferring responses, approaches and solutions from one context to another.

According to Boer, a special form of learning process, namely continuous innovation (CI) is '…the planned, organized and systematic process of ongoing, incremental and company-wide change of existing practices aimed at improving company performance' (Boer and Seferis, 2002). The basic approach in CI methodology is to combine operational effectiveness (i.e. the capability to satisfy today's customer demands) and strategic flexibility (the capability to develop new market approaches, processes, competencies, organizational and management systems that provide for the satisfaction of tomorrow's customers). As Boer and Seferis (2002) explain, CI is about using all the innovative potential in the organization in order to continuously improve the performance of the company, where the core aspects are development and learning.

Consequently, within the CI concept, OL may be seen both as a process to sustain and optimize existing operational practices in order to increase operational effectiveness, as well as a process supporting the augmentation of the adaptive capacity of a system through a better interpretation of external/ environmental factors driving change, and assisting in new goal-setting.

This should support simultaneously:

- A vertical communication process of goal-setting and deployment (top-down), and information about the company's performance (bottom-up);
- A horizontal communication process of exchanging experience obtained from performing CI activities, and improved practices.

Managing the variety/ diversity of processes, and thus the variety of contexts, requires a holistic approach to learning as a contributing factor in order to balance Strategic Flexibility and Operational Effectiveness in a Changing Environment. It is assumed that integral performance improvement contributes to the balance between safety, environmental or strategic sensitivities and business results in order to achieve sustainable development. Therefore, we are looking for well balanced company performance, and how learning contributes to it.

Since OL has become increasingly important for industry in its adaptation to change in the political and economic environments, to changing regulatory requirements, and to changing technologies and organizational models (see e.g., Wahlström et al., 2005), the system should be seen as:

- Stakeholder-based, thus with multiple-effectiveness criteria;
- Process-based, thus with dynamic, fuzzy and essentially unpredictable processes of 'organisational structuration' (H.Boer&F.Gertsen, 2003).

This concept of OL needs to apply a mechanism for the prioritization of suggestions for change, depending on the market and stakeholder-related objectives on the one hand, and work environment-related objectives, including safety, on the other. For such a prioritization, as well as for the modelling of alternatives for improved practices, theoretic decision-making models may be useful. This also applies to the evaluation of alternatives with respect to the overall goal to balance strategic flexibility and operational effectiveness in a changing environment.

Learning is a bridge between the "world-as-imagined" (design) and the world-as-experienced (situated action), where diversity may be a source for innovative problem- solving by combining types of knowledge (experience-based, specific, or pro-active). Learning, therefore, plays an important role in the transformation of existing knowledge into new design solutions, in order to reflect both organizational and human needs for change and the opportunities for such change.

Evaluation of Opportunities for Change: a Search for a Holistic Approach

The Product life-cycle is represented as an open system influenced continuously by different "design drivers" (Moir and Seabridge, 2004) – business drivers, project drivers, product drivers, subsystem development drivers, and the product environment. Thus, design drivers are those entities which perceive the need for (re)-design.

Organizational learning in the context of an open system should therefore combine the interpretation of environmental variables, the application of the impact of those variables on the organization's current and desired states, and the action taken with the new knowledge that has been created. Organizations fail to learn because the characteristics inherent in traditional decision support systems do not allow either for feedback loops at a variety of levels or for an infusion of environmental variables in problem solving. In our view, transformation occurring in the learning process takes place within decision-making, where continuous feedback loops should be integrated. The decision process should provide a certain degree of transparency, since each participant should understand not only its own benefits and losses, but also those of the other participants. Such transparency would promote learning for different stakeholders by identifying the criteria important for the achievement of common goals/ objectives; and by thinking about the meaning of individual criteria (through weighting and prioritisation) in achieving the common goals.

If one adopts the view that learning is the conceptualisation of a holistic approach for coping with diversity at the organisational and inter-organisational level as well as for increasing sensitivity towards the environment, then the focus should be on the integration (and not only generalisation) of knowledge from diverse backgrounds. Thus, a theoretical issue relating to knowledge transformation between experience and design arises: how to extend the renewal and generalisation of existing frames of interpretation to an integral level, where all voices (of knowledge drivers influencing the design) can be heard.

In an aviation network, where each company possesses both specific, non-shareable knowledge (related to commercial interests) as well as shareable knowledge of common interest (such as safety), there is both a diversity of objectives, and a diversity in understanding the ways of achieving such objectives. Conflicts between divergent objectives and between different types of knowledge (e.g., experience-based and specific; shareable and non-shareable; user-stakeholder) are unavoidable.

The process of transformation is not only about measuring the driver's objectives, but is even more about conflict resolution between divergent objectives (from company to network level), and gaining useful knowledge through learning in order to contribute to the integral, balanced performance of the company.

We argue that i) learning occurs as a visualization of those divergent objectives, and of opportunities and risks related to change/ new process -design in the search for shared ideas about conflict resolution; and that ii) the implementation of lessons learned is related to different levels of Organisational Learning: both at the reactive level – organization of working memory and reporting systems to improve the performance of today's work processes; and at the pro-active level – within the design phases, an evaluation of the consequences of design solutions/ modifications.

In order to develop a holistic model of OL, which suggests "bringing together the concept of different learning levels and step-by-step procedural change processes" (Lähtenmäki, et al., 2001), we propose to use Analytic Hierarchy Process (AHP)-based methodology (Saaty, 1989; 1996).

Davidson and Labib (2003) proposed a model for learning from failures or design improvements using a multiple criteria decision-making process, namely the AHP mathematical model. This model was built for an analysis of the Concorde accident but in our view is limited by focusing on the repetition of the same failures. According to Hummel et al. (2000), the AHP can be applied to steer design activities in the earlier as well as later development stages of a new product. Due to its explicit support for integrating diverse points of view, it facilitates the learning processes and the building of consensus between partners with diverging professional backgrounds. Research methodology based on AHP shows which design changes are acceptable. AHP helps to adapt design activities to changes in users' needs, and to steer and align the inter-organizational partners' design activities.

Our approach is based on the lessons derived from operational experience (events – accidents, incidents and/or operational concerns and successes) as a new understanding (knowledge) which identifies a solution (a specific design modification/decision or work process decision) that reduces or limits the potential for accidents, failures and mishaps, or reinforces a positive outcome. This corresponds with the definition of lessons learned which should be applicable for future missions. We propose that AHP methods can be used as a supporting tool for learning at the operational level, e.g. in Maintenance, Flight operations, as well as for learning which helps to cope with a variety of values in a changing environment at the organizational or inter-organisational/ network level. Fig. 1 is an example of the transformation of diversity with an emphasis only on the link between the operational dimensions of performance and re-design. This may be applied to process re-design in Maintenance (see Fig.3).

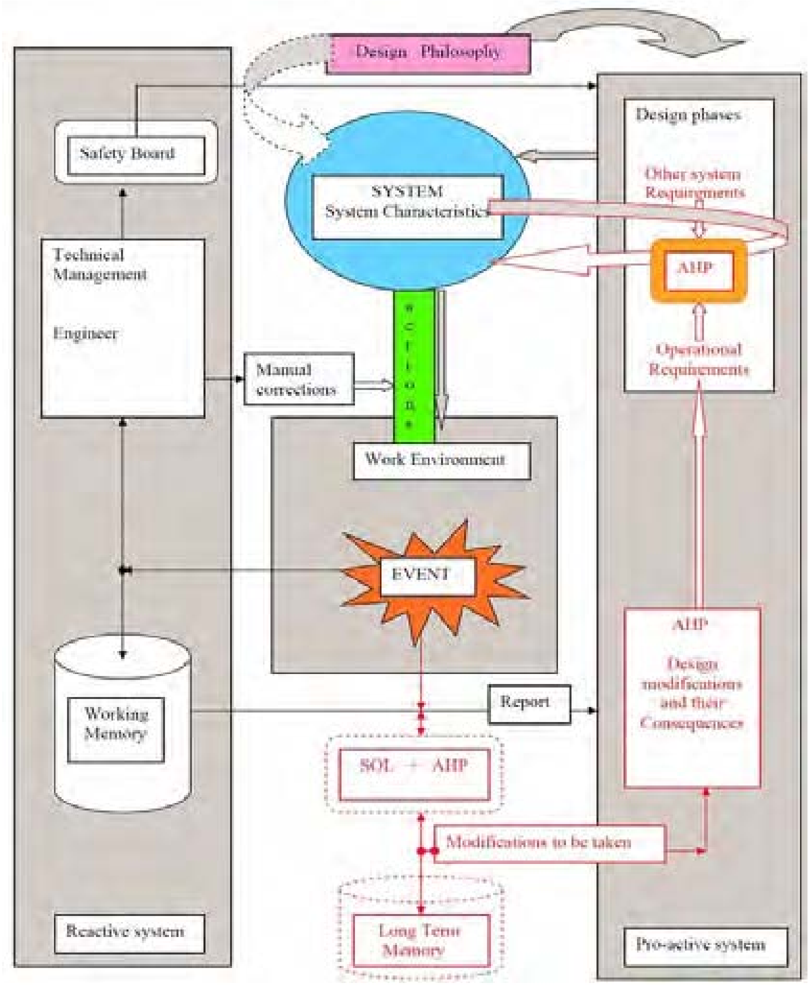

Figure 1. System's Approach to Transformation of Operational Performance into Design

In order to conduct Event Analysis we can use the SOL (Safety through Organisational Learning) model of Wilpert (1999) (see Fig.2). This model extends the possibilities of the identification of contributing factors beyond given checklists which do not include unreported factors.

We propose to reinforce the Learning Module in this model by using the AHP module (see bold lines, Fig.2) for the identification of corrective actions and the prevention of failures; and for the introduction of outcomes of such analysis into reporting systems which will help the implementation of operational lessons in the design process.

Lessons derived at the operational level from product successes and failures need to be translated into new operational requirements. They should also be the basis "for an evaluation of the acceptability of design changes" (Hummel et al, 2000). Therefore, several phases of transformation are needed:

- From event analysis to problem formulation or the identification of corrective actions;
- From the generation of a set of corrective actions and/or design modifications to the problem-solving level, i.e. the identification of possible ways in which these modifications might be carried out. The choice needs an evaluation of their consequences in terms of operational adaptability;
- Translation into operational requirements.

The proposed model relates to the function of Long-term Memory (LTM), which needs to be elaborated in order to validate the lessons which were incorporated.

A pro-active approach is essential in the further Learning Loop addressed to Design, and taking place within the Design phases for an evaluation of the consequences of badly adapted design solutions. The possibilities of such an evaluation are also given in AHP and/or Analytic Network Process (ANP).

We are developing an empirically based model of the transformation process and propose using AHP as a potential instrumental tool for supporting the integration of diverse "design drivers" and for facilitating the learning processes and the building of consensus between diverse groups in aviation and thus, as a potential evaluation procedure for knowledge transformation in organisational contexts.

We provide here an example (Fig.3), which has been developed on the basis of existing Check Lists for incidents and operational concerns.

This model supports the learning process by using data from check lists of past events as well as assumptions and expert judgments concerning factors and/ or combinations of factors potentially contributing to an incident. Therefore, this model does not reconstruct a particular incident but is a simulation exercise including a consideration of the multiple possible combinations of factors and multiple possible actions-responses.

Here AHP assists in making the most appropriate choices (backward process*) with respect to a synthesis of all available and predictable operational data, and in justifying those choices by providing transparency in such a synthesis of priorities.

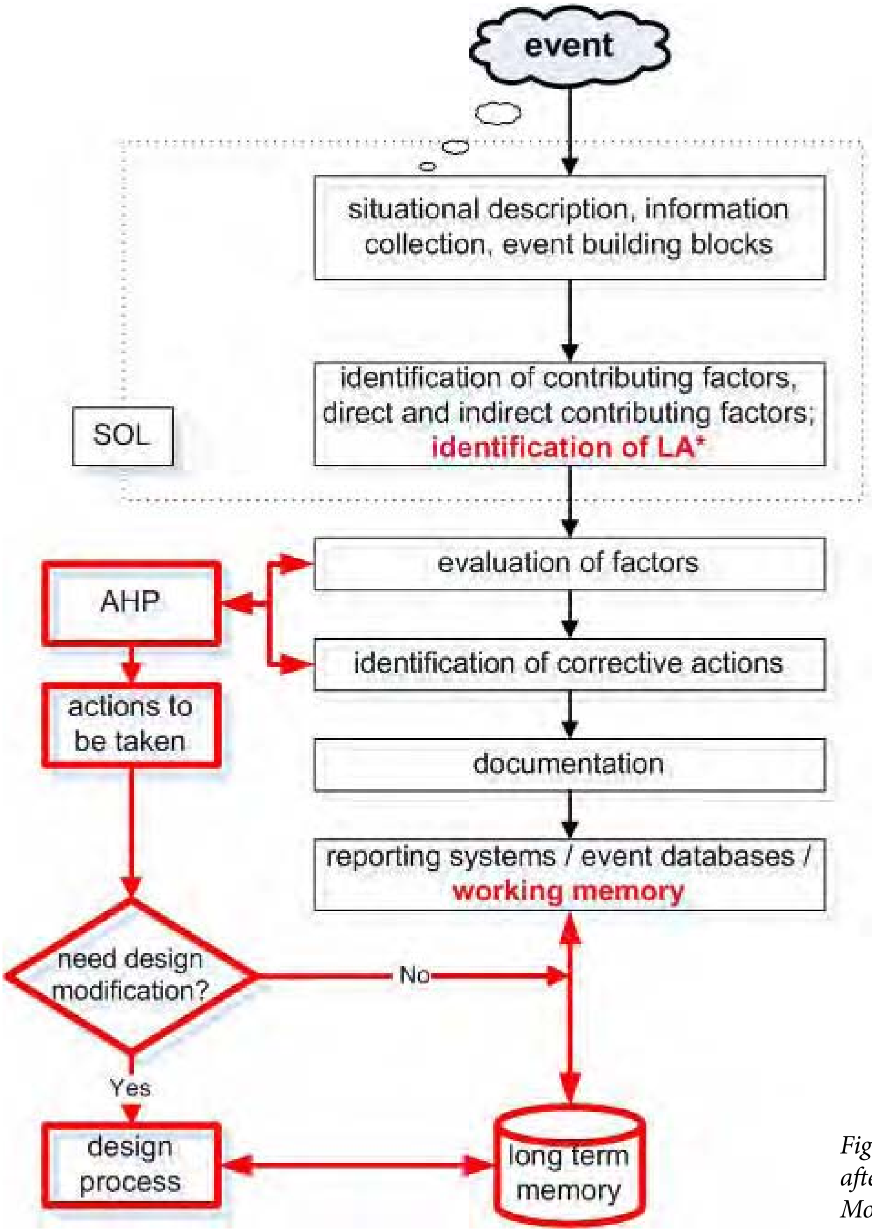

Figure 2. Modified after Wilpert's SOL Model

Towards Integrated Decision-Making for Adaptive Learning

In our view, strategic decisions concern a choice of goals, taking into consideration their multiple and variable character. As is shown in Figure 4, a

LA* – Learning Agency (Koornneef F., 2000); here this includes all processes indicated in bold lines and related to process (re)design.

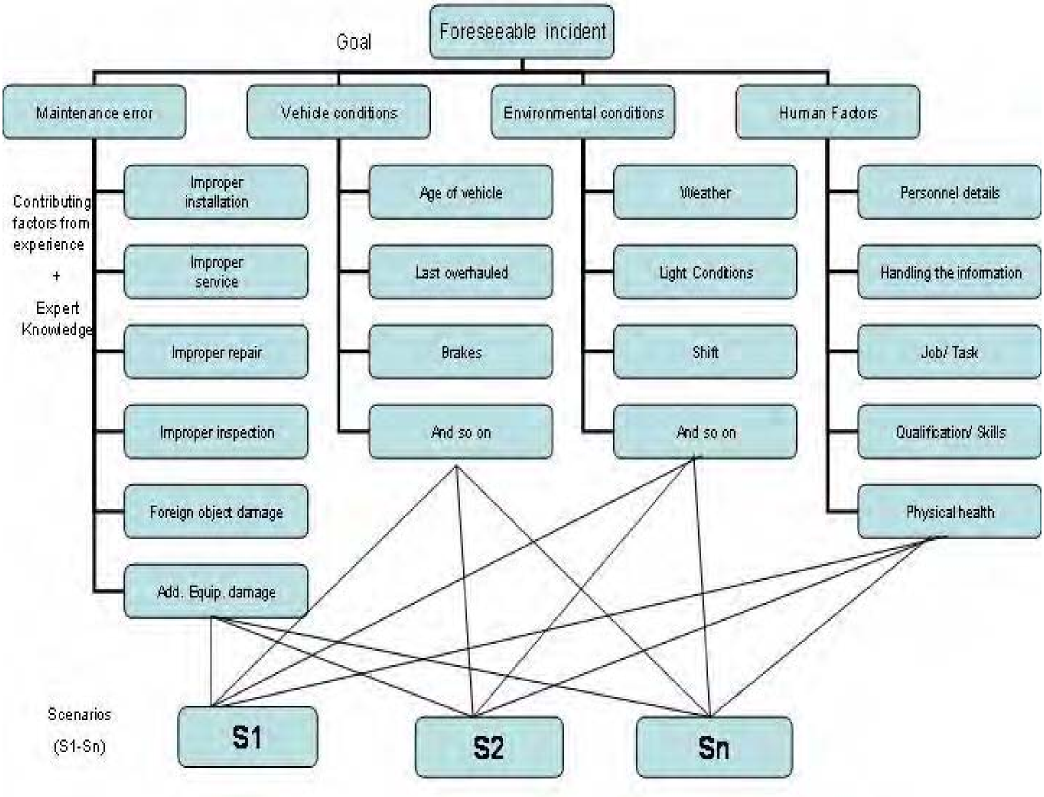

Figure 3. Supporting Learning from Experience in Maintenance

level of agreement on goals could be achieved by reverting to the normative model of management, i.e. the "Bottom-Top" model.

The idea of transferring from a normative decision approach to a sustainable decision approach by replacing "representative democracy" with "deliberative democracy" (Pesqueux, 2003) might be very useful for formulating and introducing the interests of minorities as well as for the decision-making process, and therefore for providing the principles of participatory management for the best possible sustainable decisions. As Rajeswar (2002) remarks, a bottom-top approach involves the empowerment of women and disenfranchised groups, and is a precondition of humanistic development not only in the sense of human need but also in the sense of ecological and ethical concerns. "Consensual or non-majoritarian decision-making" (Hooghe & Marks, 2001) requires a negotiation procedure at

**Choice models are sometimes referred to as "backward" processes and forecasting models referred to as "forward" processes (Saaty T. & E. Forman, The Hierarchon – A Dictionary of Hierarchies, Pittsburgh, 1993).*

any strategic level – whether enterprise, local, regional, national or international.

In considering the existing diversity of goals, it is necessary to remember that they include not only short-term objectives but also long-term priorities (see Figure 4).

In order to formulate a strategy for the development of a region, the regional administration should be a balanced system, where all components have equal importance. The quality of management and its effectiveness can be evaluated by its capacity for harmonising different components.

The vector of development is determined by a synthesis of many goals. However, it is difficult to quantify development goals such as equity, health or freedom (Rajeswar, 2002). That is why it is so important to establish operational procedures of synthesis and harmonization.

Methods that allow the appraisal of the sustainability of decisions, including factors both tangible and intangible, can be grouped, according to

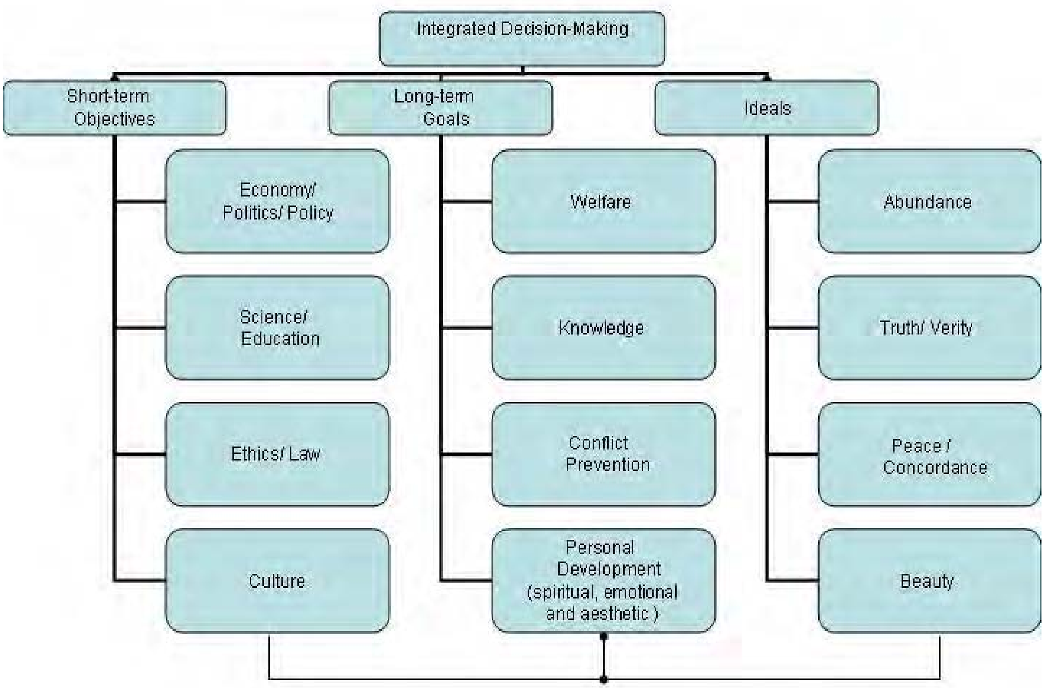

Figure 4. Linking Diversity of Objectives: towards Integrated Decision-Making.

Alker and McDonald (2003) in four types:
- Risk based assessments;
- Matrix type approaches;
- Checklist appraisal type approaches and
- Sequential approaches.

These methods have strong and weak components but allow for an analysis of the existing diversity of goals, for the promotion of better decision-making in the sense, as Medina (1996) reminds us, that public policy should make possible a better evaluation of what public programmes can offer from the point of view of social well-being.

A planning process, in our view, should be presented as both bottom-top process (introducing the diversity of goals) and top-bottom process (introducing the community goals). In addition, Lambooy, Boschma (2001) formulate the objectives for policy-making as a bottom-top strategy attuned to the needs and resources of a region and a top-bottom approach at the national or supranational level (Cooke and Morgan, 1998).

For sustainable development the top-bottom process should replace 'Development Plans' with 'Community Strategies' (Alker, McDonald, 2003). The difference between these last two is that normative planning with an orientation to economic welfare produces an unsustainable lifestyle, while Community Strategies " should be viewed as the future 'best practice' approach " (Alker, McDonald, 2003). In our view, community strategies have to play an important role in influencing gradual change in values and norms which will lead to sustainable lifestyles.

"A less resource-intensive alternative" to development would mean focusing on inner spiritual development (Mainteny, 2000). Strategic management, therefore, aims at stimulating the correct social conditions for appropriate personal development. This means that a systemic approach with regard to sustainable development requires a consideration of mutual dependence between diversity levels (individuals' goals) and community levels (common social goals).

As Mainteny (2000) emphasises, because a sustainable future depends on changes in personal human behaviour and sustainable development, change depends in turn on inner belief, as much as it depends on structural changes in society. So, strategy should be both visionary and action oriented, short and long term, participatory and representative in democratic form (Williams, 2002). In our view, changing the procedures of decision-making can be seen as a realisation of participatory democracy at the level of goal formulation.

Conclusion

Rasmussen & Svedung (2000) state that "…in the dynamic environment risk management can no longer be based on responses to past accidents and incidents, but must be increasingly proactive. To be proactive, risk management must apply an adaptive, closed loop feedback control strategy, based on measurement or observation of the level of safety actually present and an explicitly formulated target safety level."

A company in a networked and changing environment strives to reconcile two objectives – to ensure the survival of adaptive plans and also to admit change in the environment for variety and future progress. This reconciliation is to be seen as strategic, adaptive planning and thus as a process of learning and development.

If adaptive behaviour is a successful strategy for individual learning (see e.g. Vicente, 1999; Norros, 2004) then adaptive planning is also a strategy for an organization to learn. An adaptive planning process is different from one which moves only in one direction (forward or backward) (Saaty and Kerns, 1991). In the forward process, one considers the relevant present factors, influences, and objectives that lead to sensible conclusions or scenarios. The factors/ influences/ objectives may be economic, political, environmental, technological, cultural, and/or social in nature. The backward process begins with desired scenarios, and then examines the policies that might have achieved those scenarios. To integrate forward and backward hierarchical planning, one projects the likely future from present actions, adopts a desired future, designs new policies, adjoins them to the set of existing policies, projects a new future, and compares the two futures – the projected and desired – for their main attributes. The desired future is modified to see what policy modification is again needed to make it become the projected future, and the process is continued.

In this continuous process, decision-making can be seen as a strategic tool for providing dynamic stability on the basis of a diversity of objectives. This tool has a formal procedure facilitating a learning process through visualisation and then an evaluation of personal and community priorities with respect to desirable social change. The decision process should provide for a certain degree of transparency, since each participant should understand not only its own benefits and losses, but also those of the other participants. Such transparency should promote learning for different stakeholders by identifying the criteria important for the achievement of common goals/ objectives; and by thinking about the meaning of individual criteria (through weighting and prioritisation) in achieving the shared vision and common goals.

But learning is not only a matter of social development but of human development also. By linking human development, learning and decision-making we can contribute not only to 'Redesigning' but also to what Scharmer (2000) called 'Reframing' mental models and to 'Regenerating' Purpose or Will.

We believe that the principle Purpose/ Will in a long-term perspective is to extend the renewal and generalisation of existing frames of interpretation to an integral level, where all voices can be heard; to extend responsibility as duty to responsibility as freedom; to embrace 'the Whole' in its Beauty.

'Beauty is truth, truth beauty, - that is all
Ye know on earth, and all ye need to know.

John Keats

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Anna-Karin Lindberg

Biography

Role in the Project

Writer

Work/Studies today

I am a PhD-student at the Department of Philosophy and History of Technology at the Royal Institute of Technology in Stockholm. The research project I am working on is financed by the Swedish Rescue Services Agency. In this project

I study learning from accidents from several different aspects and my project will include two empirical studies. In the first of these studies about 1800 accident reports from the Swedish local rescue services will be examined. Interesting events in the reports from a learning from accident perspective will be analyzed and follow up on these events will be made, i.e. what has happened after the local rescue services has left, what kind of preventive measures has been taken etc. In the other empirical study I will identify how 34 Swedish authorities work with lessons learned. The authorities' area of responsibility concerning learning from accidents will be identified. The project also includes a study of weak areas, i.e. areas where the learning from accidents is not working.

Background

I was born in 1977 and I have a MA with ethics as a major from Linköping University. I started my PhD studies in 2004.

Contribution to this project

I have a rather newly awoken interest in learning from accidents, and I have so far had the opportunity to work with this area from three directions, partly in my main project (described above) and partly in research projects financed by the Swedish Work Environment Authority and the Swedish Environmental Protection Agency.

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The CHAIN model

Introduction

To give the word "accident" a general definition seems to be an impossible job since different disciplines uses different definitions. What is sure is that accidents happen everywhere. An accident can be caused by natural disasters such as floods, tsunamis, earthquakes etc. and others are caused by human activity. Perhaps one can say that all human activities pose hazards for human beings and/or the environment and the ecosystems. What seems to be the common feature for all accidents is that they are not wanted and that we obviously cannot avoid all of them. However, it is incredibly important that we draw knowledge from all occurred accidents and that we learn from our mistakes and failings that could have increased the accident or made the follow-up work more difficult. As said before, not all accidents are (directly or indirectly) caused by human activity but there is of course much to learn even from such accidents with the purpose to limit consequences and perhaps also to try to take precautionary measures. An example of one way to limit consequences is construction of earthquake safe buildings.

In this chapter I will present a model, the CHAIN model, and I will apply this model on two empirical studies. The intention with this chapter is to show how a model such as the CHAIN model can be used in order to analyse empirical studies on accident investigations in a systematic way.

The model

The CHAIN model was first used in an evaluation of the Swedish Work Environment Authority's accident investigation board (Lindberg and Hansson 2006), from now on referred to under its Swedish abbreviation, HAKO. The model was developed because a more comprehensive approach to the accident investigation process was needed. This model is rather simple, and that was an important criterion when developing the model since it should be applicable in several different sectors but still describe the investigation process in a functional way.

The CHAIN model consists of a chain of accident investigation steps (illustrated in figure 1).

- The first step in the CHAIN is reporting of accidents and incidents to the investigation boards from industries or other places where an undesired event has occurred.
- The second step is the selection, based on these reports, of accidents or incidents that are worth a special investigation.
- The third step, investigation, is the centrepiece of the process. It has also been at the focus of attention in most previous literature on the subject.
- The fourth step is the dissemination of the results to those affected.
- The fifth step is the prevention of accidents in places where similar accidents may occur.

One important feature of the CHAIN model is that it truly represents a chain in the sense that the total chain fails if only one of its links fails. If accidents are not adequately reported, or if the selected accidents are not such that important lessons can be learnt from them, or if the investigation

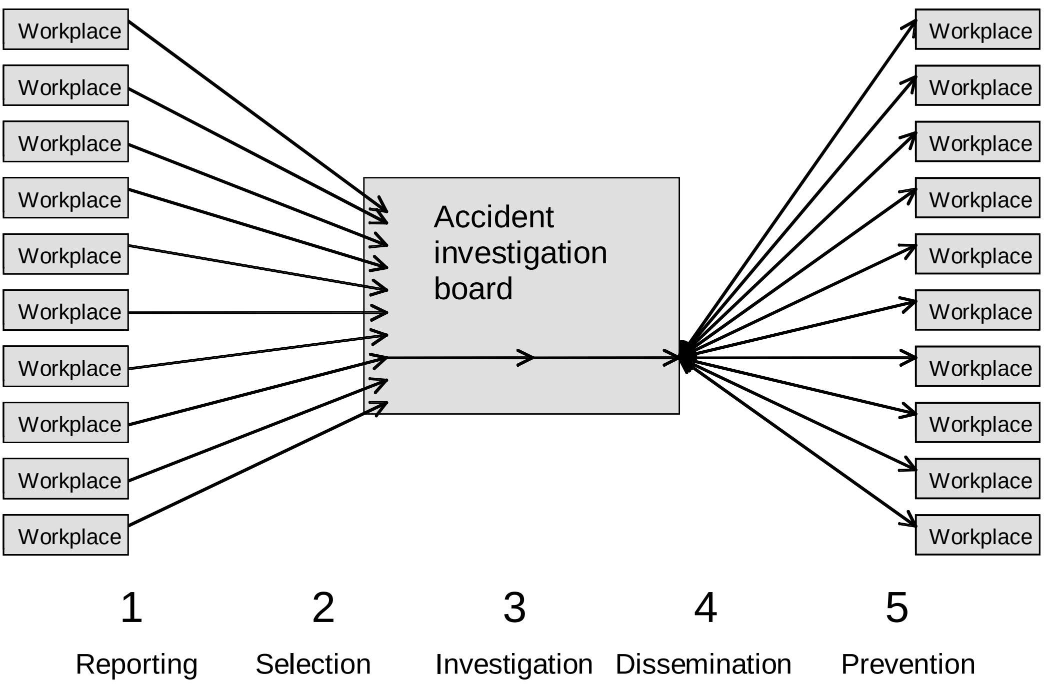

Figure 1. The CHAIN model of accident investigation and prevention.

does not find the preventable causes of the accidents, or if the results do not reach those who can prevent new accidents, or if the results do not trigger preventive action, then the whole process of accident investigation has failed its purpose.

Reporting

The first step is the reporting from accidents. Not all occurred accidents have a properly functioning systematic reporting system and the differences between different areas are large. Statistics from the Swedish Rescue Services Agency (SRSA) shows that four of five injuries caused by an accident happen in our homes and in our spare time (NCO 2006:5) but there is no systematic reporting done in this area.

Much has been written about railroad accidents in the literature on learning from accidents but primarily focus has been on descriptions of the accidents rather than on the reporting system itself.

Many industrialized countries seem to have a reporting system for traffic accidents, and incidents or accidents related to transportation in road traffic systems have been in focus in several studies (e.g. in Larsen & Kines 2002; Fabiano et al. 2005; Farchi et al. 2006; Lambert, Peterson and Joshi 2006). For instance, the Swedish Road Administration (SRA) is responsible for the Swedish Traffic Accident Data Acquisition (STRADA). Information of all accidents that lead to personal injury in the road transportation system is registered in the database. It is primarily the police who provide this database with information from accidents in the road transport system but also the medical services have the opportunity. [1]The information in STRADA is, among other things, used in investigations carried through by the SRA.

Accidents from areas with reporting systems often end up in different databases. In these databases can accidents be compared with each other. An example of a European database is the Major Accident Reporting System (MARS). MARS was set up by the European Commission and contains more than 450 accident events. Member countries of both the European Union and the Organization for Economic Cooperation and Development uses MARS to exchange reports on industrial accidents. [2]The number of

1) Swedish Road Administration: http://www20.vv.se/fudinfoexternwebb/pages/ProjektVisaNy.aspx?ProjektId=1260 (2006-06-16)

2) Major Accident Hazards Bureau: http://mahbsrv.jrc.it/Activities-WhatIsMars.html (2006-01-09)

reported events in MARS is low in comparison to other similar accident databases but the level of detail is high (Kirchsteiger 1999b).
In one way the reporting step is the most important in the chain because it is normally not possible to recreate information and knowledge from an accident. Evidence and memories disappear if it is not taken care of at once. That is why all necessary information needs to be stored as soon as possible after an occurred event and that it is essential that all the information needed to make a thorough investigation is included.

Selection

The second step is the selection of accidents or incidents worthy of a special investigation. Not all accidents can be investigated and it is not even desirable. The selection of accidents can be done from different principles. One possibility is to choose representative accidents; another possibility is to select special accidents, i.e. accidents with unknown causes. It is also possible to choose accidents with particularly serious outcome. Some accidents are excluded due to lack of resources and others because the causes are already known.
Yet, the selection of accidents is often made rather thoughtlessly, for instance without special procedures for how to make the selection and research studies seem to be quite rare.

Investigation

The third step in the CHAIN model is investigation. This is the step in the model that has been most frequently described and analysed in the previous literature. The investigation of an accident can be made in several different ways for example it can be made by a special investigator or a temporary appointed investigation group. Terry Baxter (1995) has argued that an independent accident investigation is the most effective and efficient way to carry out an investigation. Nevertheless, such independent investigations are not a reality today according to a recent European study (Roed-Larsen et al. 2004).

The procedures for the investigation work are important. If there were any people involved they should be interviewed one by one. All information should be analyzed and presented in an accident report. The report should contain specified times for the events of the accident, photographs

or sketches of the accident scene and, if any, technical attributes.
A thoroughly accomplished investigation report should not only contain knowledge on how to prevent similar accidents but also information on what went wrong in this particular accident and how to limit the consequences. For example if there were any technical or organisational failures in the rescue action performed by the local rescue service. Information of this kind does not prevent future accidents but it can minimise the consequences of such accidents. Causes of an accident can be psychological, technical or organisational (Rollenhagen 2003). Psychological and technical causes have been in focus for a long time in the literature on accident investigation. However, today one of the recurrent themes is that also organisational causal factors are of interest. Dien et al. (2004) have pointed out that accidents and incidents are products not only of technical failures and human errors but also of unfavourable organisation conditions that often have a long history.

Dissemination

Dissemination is the fourth step. This is an important step but too often it seems like this step has been neglected. When we have come this far in the CHAIN we also need to make an effort to find the people who should see the report. Several authors have emphasized the importance of spreading knowledge from accident investigations widely. Companies need systems for dissemination of the reports to all those who might be affected (Jones et al. 1999). The hard part is seeing to that the lessons not are forgotten. Both new and old accidents should be described and discussed in safety newsletters and on safety meetings, knowledge from people with long experience should be taken care of, serious accidents should be included in the training of new recruits, and old reports should be made more accessible (Kletz 1993).

Yet it is important to remember that even if statistics of past accidents can provide useful information about an event it is not possible to predict with absolute confidence either where, when or under what circumstances an event will occur (Kirchsteiger 1999a). Or perhaps it is as Kletz puts it: “Even when we prepare a good report and circulate it widely, all too often it is read, filed and forgotten” (Kletz 2002, p 5). Because organizations have no memory, only people have memories and after a few years they move on taking their memories with them (Kletz 2002).

Prevention

The prevention step is important but it has not been noticed as much as needed in the literature. It is difficult to say to what extent a preventive measure really is affected by lessons learned from other accidents but the accident investigation process has not come to an end until its recommendations have been implemented for the future safety of the system to be protected (Johnson and Holloway 2003). An investigation of an accident which leads to recommendations is just one step along the way, the investigation is not in itself improving safety or preventing accidents. The real change takes place when implementing these recommendations (Sweedler 1995).

Learning from an accident investigation board of workplace accidents

The CHAIN model has been used on an empirical study, namely an evaluation of an accident investigation board in management under the Swedish Work Environment Authority (SWEA).

SWEA is the administrative authority for workplace health and safety. SWEA's aim is to reduce the risk of ill-health and accidents in workplace and to realize the public policy objective of a good work environment for all. It consists of four departments: Inspection, Administrative affairs and information, Legal affairs and Central supervision. The inspection department consists of ten local districts (labour inspectorates) and these districts carry out all inspection.

The accident investigation board, HAKO (Haverikommissionen) started working as an operative unit under SWEA's management in 2001. Its purpose was to tighten up the authority's workplace inspections and make them more efficient. It is their responsibility to create a deeper and broader understanding of what causes accidents and to disseminate this information both internally and externally. The investigation carried out by HAKO are built on the MTO-analysis (man-technology-organization). According to this method, the event should be divided chronological into subevents, the direct causes should be elucidated and connected with underlying factors. The board performs careful investigations of a very limited number of accidents. A HAKO investigation does not replace investigations carried out by the labour inspectorates.

HAKO's work was evaluated in 2004 (Hansson and Lindberg 2004, Lindberg and Hansson 2006) and the CHAIN model described above was used in order to estimate their work.

The reporting step was not within HAKO's control but seems to be functioning adequately since there is an extensive accident reporting system on which HAKO draws. Every Swedish employer is legally required to report work-related accidents and incidents to SWEA and these reports are registered electronically. It is easy for HAKO to monitor the accidents that occurred and search for accidents that match their selection criteria.

The next step is the selection. HAKO does not investigate all workplace accidents and therefore uses the following selection criteria: accidents in the building and process industries, accidents involving heavy machinery, accidents involving several employers, accidents that can generate significant media interest, accidents of national interest, and fatal accidents. Not all events that match these criteria are investigated. This step seems to be well functioning because there were important lessons for prevention that could be drawn from all of the accidents selected for investigation.

The third step in the CHAIN model is the investigation step. During its first years HAKO has succeeded in establishing a high qualitative level in their investigations of workplace accidents that should be significant for such investigations in general. The evaluation has shown that the reports are thoroughly written and that it is possible even for a layperson to read and learn from them. Through the method HAKO uses they have found not only the direct causes of the accidents but also underlying technical, human and organizational causes. HAKO uses the following investigation criteria:

1. Course of events. A detailed description of the event should be made, clarifying the contributions of different subevents.
2. Graphical representation. A graphical representation should be made of the chain (or backwards branching tree) of events. It should include both technical and organizational causes.
3. Underlying causes – organization. A careful analysis should be made of the underlying organizational causes. This may include instructions, education, division of responsibilities, routines for learning from experience, and the general safety culture.

3a. Underlying causes – persons. Underlying causes that concern the adaptation of technology and organization to individual persons should be carefully investigated. This may include mental overload, disease, temporarily reduced work capacity, understimulation, reduced powers of reaction, lack of time, lack of knowledge, insufficient or inadequate instructions, lack of training, unsuitable work method, inappropriate forms of shift-work, and deficiencies in planning.

4. Direct causes – organization. A careful analysis should be made of direct organizational causes. This may include the decision to perform the work operation in question and the decision how to perform it.
5. Underlying causes – technology. A careful analysis should be made of underlying technological causes. This includes safety devices, safety relevant maintenance routines, safety margins, adaptation of the process to possible human mistakes, and reductions of inherent risk by the choice of appropriate technologies.
6. Direct causes – technology. The accident event should be carefully analyzed from a technical point of view. This includes device failures and deficiencies in equipment and materials that may have contributed to the accident.
7. Legal failure analysis. Based on items 3-6 it should be determined which of these deficiencies are connected with insufficient adherence to laws or regulations, in particular regulations on workplace health and safety.
8. Conclusions and recommendations. It should be stated what measures need to be taken to avoid recurrence of the same type of event, on the same or other workplaces. Every proposed measure should be addressed to someone with responsibility for implementing it.

When it comes to HAKO's work, a link in the chain in great need of improvement is the dissemination. It is essential for the learning possibilities that the reports are disseminated properly. To get the maximum benefit of an investigation it takes a well-considered strategy to disseminate information. A finished HAKO report is only published on the SWEA website and we have therefore suggesting that HAKO takes two rather simple measures: dissemination through a mailing list and publication on a special homepage for HAKO. In general the dissemination seems to be the weakest link in the chain and it leaves considerable scope for improvement.

The final step, prevention based on the reports, was not covered by our investigation of HAKO but we have made some recommendations for improvements in order to facilitate the use of HAKO reports in practical accident prevention. We have recommended HAKO to specify a clear addressee for all proposals in the reports and that SWEA sets up an internal system for follow-up, including follow-up meetings for all finished reports.

In summary, the evaluation of HAKO's first years as an operative unit shows that the dissemination of the reports is the weakest link in the CHAIN model, see figure 2. SWEA has been investigating how deep studies are to be conducted within the authority and HAKO has not been active during this time.

Learning from municipal inspectors knowledge

The CHAIN model has been used on the empirical study of environmental supervision in Swedish municipal districts.

Sweden is divided in 290 municipal districts. These districts are responsible for the supervision in accordance with the Swedish Environmental Code, the Food Act, the Animal Welfare Act etc. The supervision activities include environmentally hazardous activities, food handling, public indoor environments and animal husbandry. [3]One task for the municipal inspectors is to secure the purpose of the Environmental Code by strengthening the operators' internal control and by controlling how they follow the observance of the Code (Swedish EPA Manual 2001:4). The operative work of supervision is performed by an environmental inspector.

There are several authorities responsible for supervision issues on a national level. For example, in total fourteen different national authorities have as one of their tasks to guide municipal authorities in their inspection work[4] and twenty-one County Administrative Boards have responsibilities related to several of the legislations.

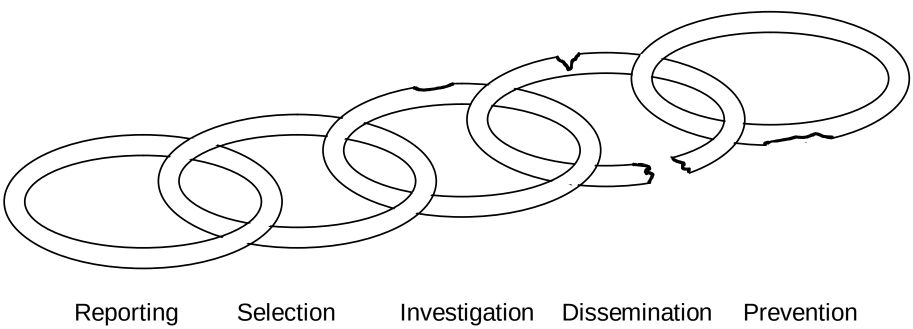

Figure 2. A summary of strengths and weaknesses in the operations of HAKO.

3) City of Stockholm: http://www.stockholm.se/files/86000-86099/file_86087.pdf (2006-06-15)

A recent study (Swesiah EPA report 5600) has shown what can be learnt from municipal supervision cases. Eleven municipal Environment Protection and Public Health Departments were contacted and asked to choose examples of seriously bad cases that they have encountered in their supervision work and also other interesting cases. Twenty-eight different cases were handed in. These have been analyzed with the intention to show what can be learnt from them. Interviews were conducted in all cases with the inspector in charge. The supervision cases have shown two main areas in need of improvement concerning learning from accidents and incidents. These are:

- Experiences from the juridical system.
- Lessons learnt concerning co-operation and support from the regional and central authorities.

According to the Swedish Environmental Code the municipal inspectors are bound to report violations of the Code to the public prosecutors. The inspectors seem to be in need of guidance of how to handle this legislation. Several of the supervision cases show that the public prosecutors often drop preliminary investigations for different reasons. Another aspect of learning from accidents is that the inspectors want to be informed by the prosecutor of what happens with the cases. This should be done regularly but it is not a reality today. The police and prosecutors investigation time is far too long, and the inspectors do not know if their cases have been dropped or if it still is in abeyance. The inspectors also want to be informed about what happens with the environmental penalty charge imposed by the court. The lesson is that the inspectors are in need of feedback concerning legal matters and that they want to get some kind of closure of the cases.

There are many authorities involved in environmental supervision and they have to co-ordinate to be able to derive advantage from lessons learned. The inspectors have in interviews mostly mentioned the regional co-operations. Supervision-projects with the aim to strengthen and make the supervision more effective have become a popular element and these projects are often carried through within regional collaborations. These regional collaborations are about to force the central authorities out of competition. The reason for this is perhaps that the inspectors do not think the central authorities support is enough.

The CHAIN model is not completely applicable on municipal super-

4) The Enforcement and Regulations Council, Marie Eriksson (2006-08-22)

vision and only fragments of the chain have been found in this study. A reason for this is perhaps the number of authorities involved. As in the case with HAKO there is only one authority responsible for the learning process but there are several hundreds of local authorities involved in the environmental supervision and they are in all essential responsible for the systematic learning from accidents and incidents.

The reporting step is in municipal supervision mostly dependent on the inspections and that the operators and the public report disturbances. How this really is working is hard to say since it is not possible to know what is not reported. The selection step is not relevant because the municipal inspectors investigate all environmental disturbances they discover. Investigation is a part of the municipal supervision. The inspectors investigate environmental disorders but they do not produce accident reports like HAKO does. Instead they investigate an accident or incident as far as their jurisdiction allows and then they hand it over to the police and the prosecutors. This study has shown that the inspectors do not have special paths for dissemination of lessons learnt from an accident or incident, not to the supervision objects nor to other inspectors or other authorities, on a systematic manner. The final step, the prevention of accidents and incidents in places where similar events may occur, is an important step for the inspectors since prevention is a fundamental element in supervision.

Reflections and conclusions

All accidents cannot be prevented but still we have to try to reduce them and limit their consequences. Learning from accidents and incidents should therefore be highly prioritized.

The literature on learning from accidents is very much concentrated to major accidents which perhaps are understandable but still misleading, since for example statistics from the SRSA shows that four of five injuries are caused by accidents in our spare time and in our homes (NCO 2006:5). NCO has published a report that shows that a majority of the Swedish people believes that most accidents with deadly outcome happen in the road traffic. According to statistics from the SRSA such accidents are only responsible for about 16 percent of all accidents with deadly outcome. Most accidents were in fact fall accidents; almost 49 percent of all accidents with deadly outcome. It is also an interesting fact that 75 percent of the research resources are invested in work environment safety even though these accidents are only a small fraction of the total number of accidents.

Only 5 percent of the funds go to research studies on fall accidents (NCO 2006:5).

It can be difficult to identify such accidents. In Sweden it is probably the Swedish local rescue services that work with the widest spectra of accidents. Irrespective of what caused the accident (natural disaster, human activity etc.) it becomes a commission for the local rescue services that are located at municipalities all over the country. The main task for the rescue services is to reduce damages in case of an accident and to be damage and accident preventive. How the learning from accidents work in the local rescue services will be the subject for a research project in progress.

The CHAIN model has in this chapter been applied on two different empirical studies. This model is to some extent normative in the sense that all of the links in the chain have to be working properly, i.e. if one link fails the whole chain fails. Much of what the CHAIN model demands could, according to that, be found in the work of HAKO but less in the municipal inspector's work. This gives the impression of a weaker systematic learning from accidents within the environmental supervision. Perhaps the investigative approach is what separates them the most and the difficulties in the dissemination step what unites them the most.

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Biography

Role in the Project

Writer

Work/Studies today

Scientific Officer working for 7 years in the Major Accident Hazards Bureau (MAHB), at the EC-JRC in Ispra, Italy. A chemical safety and risk specialist with a focus on industrial risk assessment, accident reporting and analysis for the purposes of lessons learning etc. Duties include the continuous development, operation and management of the Major Accident Reporting System (MARS) and the Seveso Plants Information Retrieval System (SPIRS), which are essential components of the application of the Seveso II Directive (Articles 14, 15 19 and 20).

Background

Received a Masters degree with Honours in Chemical Engineering from Loughborough University, UK, and a PhD in the area of Safe Process Design also from Loughborough University.

Contribution to this project

Since I have extensive experience in the field of accident reporting and analysis for the purposes of lessons learning, I have contributing towards this concept of "learning from accidents" from both the broad perspective and the more in-depth viewpoint of the chemical industry. In particular I propose an extensive methodology for learning at the heart of which is the philosophy of information-sharing. The methodology can also be broadly applied across many fields and facilitates both the in-depth analysis of individual cases and more statistical-type of analyses.

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A methodology for learning lessons in the chemical industry

Introduction

Industrial chemical accidents can have a major impact on society not only because of the immediate harm they can cause to man and property (Toulouse , Enschede), but also because of their potential adverse long-term effects on the environment (Baia Mare). This has clearly been recognised through the development of legislation such as the "Seveso II Directive" and its amendment , , and by work carried out by international organizations such as the European Commission (EC) and the Organisation for Economic Co-operation and Development (OECD). Approaches to tackling this problem have been put forward such as appropriate land-use planning, risk assessment (safety reports), emergency planning etc. However, it is also acknowledged that learning from history is very important in order to avoid making the same mistakes, and many accidents that materialise now have occurred previously possibly with less severe consequences, possibly in another country or another industry. It has been clearly stipulated within the Seveso Directives that the operators, competent authorities, and the European Commission all have obligations to investigate, collect and report information concerning 'major accidents' and share and implement lessons learned. A thorough examination of the causes, circumstances, evolution, consequences and responses to these past accidents generates valuable lessons that can contribute towards future accident prevention and/or mitigation. Before an examination can take place however it is necessary to collect and organise accident information into a suitable format for analysis. The Joint Research Centre of the European Commission supports this goal by ensuring that the information available throughout Europe (and from the OECD) on the occurrence of technological accidents is systematically collected. More specifically, it maintains the Major Accident Reporting System (MARS), which manages information on 'major accidents' in the chemical industry in accordance with the provisions of the European Seveso directives.

This chapter outlines a methodology for learning lessons and introduces the European Community's MARS database to demonstrate the methodology in practice. One of the reasons why accidents keep occurring is that the lessons from past events have either not been learned or communicated in a systematic way, or they have not been translated into existing risk-management practices. Therefore it is important that the lessons learned are incorporated into all phases of safety management systems. The importance of Safety Management Systems has long-since been recognized , , , but the author would like to emphasis in particular the role of chemical process design in learning and preventing accidents.

The methodology

Definitions and terminology

In the absence of a harmonised terminology we use the following definitions for the purpose of this article:

Accident: An unintended and unforeseen event or series of events and circumstances that results in one or more specified undesirable consequences.

Hazard: A source of danger . A hazard does not necessarily lead to harm but represents only a potential to result in harm.

Risk: The combination of the frequency, or probability, of occurrence and the consequence of a specified hazardous event . Risk therefore includes the likelihood of conversion of a hazard into actual delivery of injury, damage or harm.

Lesson learned: Knowledge gained from investigation, study or other activities in regard to the technical, behavioural, cultural, management or other factors, which led, could have led, or contributed to the occurrence of an accident .

Chemical Process Design

Before describing the lessons-learning methodology it is important to understand the chemical production process through its different stages from conceptual design through construction to full production. A chemical/process engineer comes up with a conceptual design by studying the demands, considering business needs and economic viability, choosing unit operations, component configurations etc. As Beauchamp explains in her chapter designers usually use "available knowledge", whether internal (based on own experience or learning) or external (based on others' experiences, and existing or new research). They focus on a single design concept and then optimise it rather than generating new concepts. The design is further refined by a team of experts from the design, construction and operation fields and includes specialists in chemistry, process control, mechanics etc. using an iterative process (including safety reviews, such as hazard and operability (HAZOP) studies). After a final design is established, with all relevant issues resolved, the plant is constructed and all the necessary equipment is installed and tested before production can begin. In particularly innovative (and potentially hazardous) designs a pilot plant may be constructed in order to test whether the chemical processes carried out within a laboratory can be performed on a larger scale, before going into full production. At the same time the management of the plant is established including the safety management system, written operating instructions, trained operators etc. A high-quality design results in an inherently safer plant .

Description of the methodology

The methodology outlined below discusses the major steps in the lessons-learning process (Figure 1), and is adapted from a broader methodology used for learning from both natural and technological accidents . Due to its generic nature it should be applicable on any geographical scale (international, national, regional or local), and many large multi-national chemical corporations already have this type of scheme in use. The methodology integrates both the in-depth analysis of a single case and the more generic trend-type analysis of multiple cases. It also enables the updating of previous lessons learned studies with information from new events.

If all the steps in the chemical process design and installation have been carried out correctly, there should be a minimum of problems. Unfortunately this is not always the case, and sometimes something that is overlooked in the design, construction and production process can initiate a sequence of events leading to an accident. It is not always clear what this trigger may be or what the sequence of events are so in the event of an accident (or near miss) it is necessary to carry out the following process in its consequential steps in order to learn from it:

1. Accident Investigation
2. Accident Reporting
3. Data Collection
4. Data Analysis
5. Generation of Lessons
6. Implementation of Lessons Learned

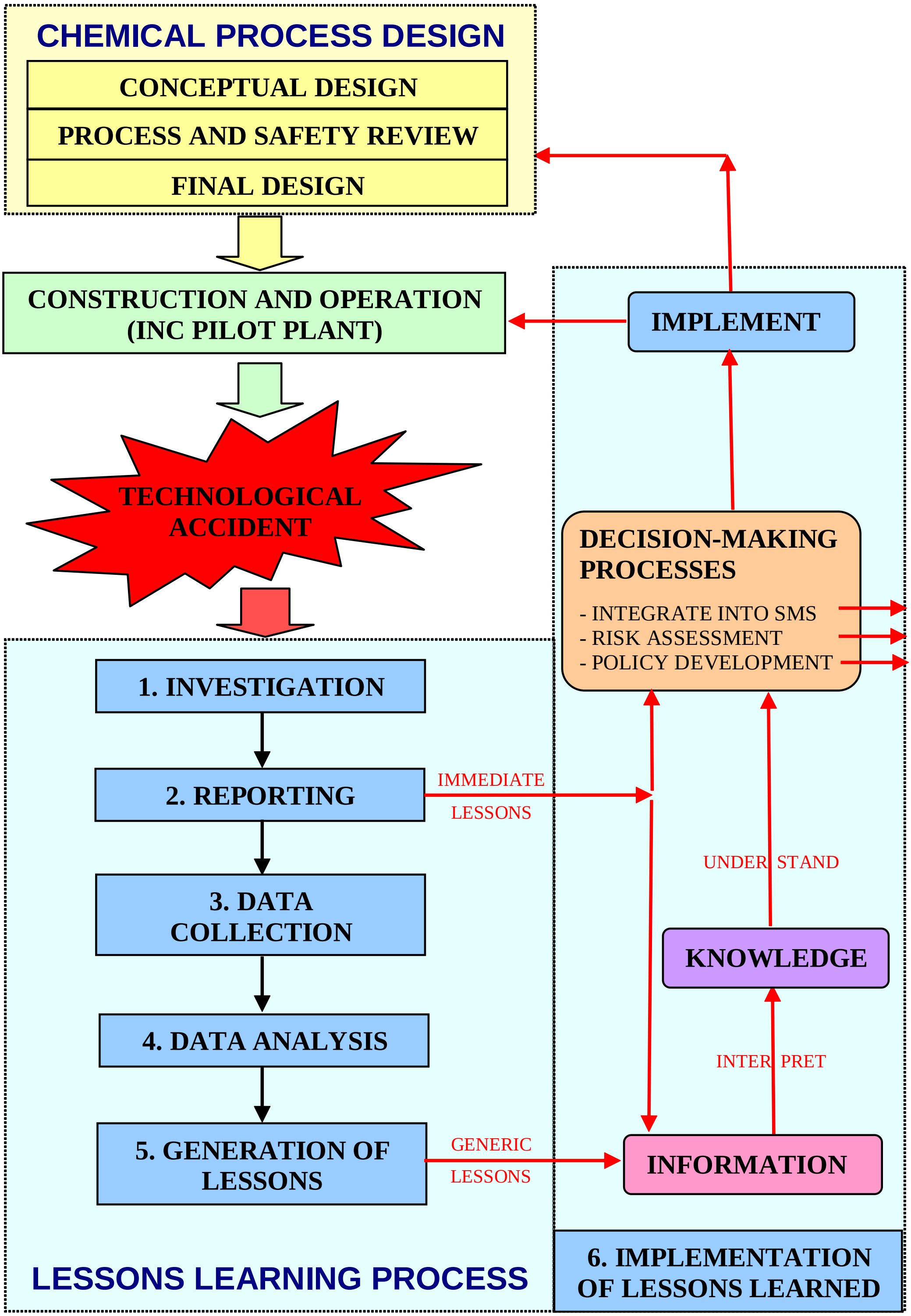

Figure 1: Schematic description of the lessons-learning process

The lessons learned should not only deal with the plant in operation but the whole process described above including the process design, construction, safety management system etc.

Step 1: Accident Investigation

The investigation of the circumstances of an industrial accident should focus on the identification of the causes and underlying causes, the circumstances leading up to the accident, and an assessment of the consequences (to provide a possible evaluation of the effectiveness of the existing safety systems). Consequently, the investigation should result in recommendations on how to prevent the recurrence of the same or similar accidents and to improve existing, or introduce additional, safety measures to lessen the consequences of future events.

There are numerous approaches to accident investigation applied across different fields, and also different ways to evaluate their usefulness . However they all share the same underlying philosophy and comparable steps, if performed accurately, which are described below:

1) Define the scope to clarify ideas and set the boundaries within which the investigation is to be conducted,
2) Gather information to understand the circumstances leading up to the accident,
3) Analyse the information to determine the root causes,
4) Make recommendations to prevent/mitigate future accidents, and set priorities.
5) As a final step an investigation report addressing the steps listed above and containing a set of immediate lessons learned and accompanying recommendations specific to the investigated event should be produced.

Clearly, the outcome of the investigation in terms of lessons learned is determined by the protocol used to investigate and report the event, and in particular by the scope of the investigation. Investigative objectives such as defence against litigation and regulatory actions or the identification of regulatory violations are usually not conducive to the generation of effective lessons learned, as the investigative findings are rarely openly disclosed or are often limited to establishing the party or agent responsible for an accident instead of determining its root cause . An expert or group of experts is required to carry out this first step in terms of drawing together information (taking photos, conducting interviews etc.), understanding the process in order to determine what went wrong and making recommendations. The accident investigation report is very important in terms of disseminating what has been learned; often it is publicly unavailable or not structured well and useful information is lost. The lessons learned (and a summary description of the accident) should always be openly available even if the rest of the report is kept confidential.

Step 2: Accident Reporting

Immediate lessons can be learned from individual accidents, which usually apply very specifically to the same or similar plants. These should normally be included in a distinct section of the final report of an investigation, and usually involve specific actions to be taken to prevent a recurrence. These lessons can also be distributed immediately as "alerts" for the industry and regulators. Complementary to this, more generic lessons can be learned from analysing the reports of similar accidents to find common elements or areas of particular concern. Essential to this is the quality, format, and detail of such reports as well as their availability and accessibility.

The data collection, as discussed in the next section, is a very difficult and time-consuming activity. It considerably benefits from legally-binding obligations to report information. Moreover, lesson-learning type studies benefit from systems that require the outcome of an investigation into an accident to be reported to a centralised location where the data can be collected, analysed and shared. Rules are required for these systems to function effectively, which can be facilitated by targeted legislation, such as the Seveso II Directive (and amendments). Additionally Annex VI of the Directive defines a 'major accident' as one which satisfies a pre-defined set of criteria related to the extent of damage or harm, so the accidents reported all comply with a uniform severity level.

Step 3: Data Collection

As mentioned previously the collection of relevant information on the evolution of technological accidents is a very time- and resource-consuming activity, however it is necessary for the lessons learning process. The mandatory reporting of information by designated bodies in fulfilment of regulatory requirements is a pro-active and effective means by which to gather validated high-quality data. Data collection from other sources such as open literature or media sources can be extremely cumbersome and a significant effort has to be expended in corroborating the various data sources to guarantee the quality of the collected information.

Data collection through mandatory reporting is one approach to gathering information. It is based on the definition of data requirements considered essential for an in-depth analysis of an event and the learning of lessons by a group of experts. This approach typically yields a considerable amount of very detailed information (both quantitative and qualitative) in a specific field of application, e.g. the chemical industry. One shortcoming, however, is that having a number of different reporters, e.g. one for every country in the European Union, inevitably leads to variability in reporting quality.

In the absence of reporting obligations, information on past accidents can be collected by means of predefined templates that should be developed in close cooperation with authorities and experts in order to address their needs and to ensure the practical application of the lessons learned generated. This approach results in the collection of data of a rather generic (and often shallow) nature, which consequently enables the detection and appraisal of common elements resulting in the development of basic lessons learned for specialised subjects e.g. fires in buildings, ammonia storages etc.

Irrespective of the approach employed for the data collection, the accident information should be compiled into an interactive database, where data can be inputted directly by the users and the database can be interrogated to support the data-analysis process.

Step 4: Data Analysis

The data collection focuses on assembling the information from the original investigation reports into a suitable format, in order to perform a supplementary in-depth analysis on the total data-set. Additional findings pertaining to the identification of trends and areas of interest concerning the causes and consequences can be extracted from the examination of the compiled information on similar accidents.

The structuring of the collected data (e.g. into a database) is dependent on the type, quantity and range of information. It is necessary to organise large quantities of data into distinct and well-defined sections to facilitate effective storage and retrieval. Fundamentally, the more extensive the information, the more sophisticated the structure required, and the greater the significance of the interrogation. Once the database is sufficiently populated with high-quality data the user should have the possibility to perform statistical or trend analyses, preferably by means of a built-in query tool. If a database cannot be interrogated then instead of being a valuable information source it becomes an information sink. As a final step, the outcome of the data analysis needs to be evaluated by using either expert judgment or systematic tools.

The usefulness of the data analysis is highly dependent on the quality of the collected information. Therefore it is imperative that there are administrators or managers, especially in the case where there are multiple reporters, to control the accuracy, consistency and completeness of the data in the database.

Step 5: Generation of lessons

Lessons can be learned in all phases of risk-management, i.e. prevention, mitigation and emergency response (both in the short and long term). The investigation of a single accident ideally results in the development of immediate recommendations to prevent or mitigate the recurrence of the same event, and may be applicable to other similar sites. The reporting and the collection of supplementary information expands the data cache available for learning lessons, and thus permits the analysis of a number of similar occurrences, which results in the generation of lessons learned that are more widely applicable than the immediate lessons learned. Additionally accident causation trends identified are another type of lesson as a number of similar accidents can indicate an underlying problem that is not the most obvious cause of any one accident but is involved in some way in all the accidents; usually this is some kind of management/organizational failure, but can also be the conditions, equipment type or even substance involved. Expert judgment is required to determine whether the information that the analysis is indicating is in fact correct, or it may be due to some outliers, erroneous reporting etc.

Step 6: Implementation of lessons learned

A lesson learned is information which needs to be interpreted in the appropriate context to build on existing knowledge, and this in turn needs to be understood in order to use it. It is probably the most difficult part of the lessons learning process to define and put into practice. The implementation of lessons learned into safety management begins with the dissemination of the findings from the analyses of accidents. This can be achieved by setting up platforms for the exchange of information between all the actors involved. This can be built on by the organization of training courses or workshops in which expert knowledge can be shared and expanded. The lessons learned can be targeted to responsible authorities, urban planners, the general public or any other stakeholder, but their implementation should be directed to have the greatest effectiveness on systems. Lessons learned should not only exist in the memory of people because they can be forgotten; where possible they should be incorporated into the memory of systems, i.e. documented in the written operating procedures, implemented into process control systems e.g. auto-shutoff valves on high-level alarms, so there is no need for an operator to remember what a particular alarm is for, etc. Where this is not possible lessons should be available as an additional source of existing knowledge for decision-makers, whether designers of systems, land-use planners etc.

Incorporating lessons learned into safety-management practices is sometimes accompanied by policy development, either by the preparation of new legislation or by bringing about the amendment of existing regulations (e.g. the amendment of the European Seveso II directive after the major accidents in Toulouse, Enschede and Baia Mare). Another of the numerous areas that can benefit greatly from the integration of lessons learned is risk assessment, and in particular the hazard-identification and scenario-development stages.

The effectiveness of implemented lessons learned needs to be monitored continuously to verify the adequacy of the updated risk-management measures. This can, for instance, be achieved by comparing the success of risk-reduction practices implemented in places with different safety cultures and hence with different approaches to accident and disaster management. This is actually very difficult in practice, and requires monitoring over several years, for instance in the case of the Seveso Directive some improvements might not be noticeable immediately, but over a number of years the quantity and magnitude of accidents occurring might be reducing due to the amendment.

Application of the methodology

The European Community's MARS database facilitates steps 2, 3 and 4 of the lessons learning methodology by enabling the reporting, collecting and analysing of information in a systematic way. It also contributes significantly to step 5 which is the generation of lessons but of course this is heavily reliant on the expert user. MARS is extremely dependent on the reporters of the database (and of course the accident investigation from where the information originates), but these reporters all have different needs whether they are plant inspectors, land-use planners etc. A new Technical Working Group for Accident Reporting and Analysis made up of MARS users, experts and industry representatives, was set up to oversee the database's future development, but with an extended mandate to look further into related lessons-learning activities such as accident investigation and the implementation of lessons learned.

Technological accidents within the scope of the Seveso II Directive

The Major Accident Reporting System (MARS) was established to handle the information on "major accidents" submitted by Member States of the European Union to the European Commission in accordance with the provisions of the Seveso Directive and then later the Seveso II Directive, specifically Articles 14, 15, 19 and 20, and Annex VI (which provides the criteria for reporting in terms of the severity of consequences). The articles are principally concerned with responsibilities for the collection and submission of information relating to the circumstances of the accident, and to ensuring the distribution and analysis of the information in order to prevent major accidents from recurring. In many cases, the persons providing input to the MARS database are plant inspectors and accident investigators working for the Member States' Competent Authorities without English as their native language (English being the working language of MARS). Therefore, the Major Accident Hazards Bureau (MAHB) of the European Commission's Joint Research Centre that hosts and manages MARS carries out a quality-control check on all submitted reports before they are incorporated into the shared database.

The structure of MARS, whose current format is shown in Table 1, was first established through a Technical Working Group (TWG) of experts in the 1990s. Initially, the system consisted of paper reporting, but the database has been continuously improved since, and the current version is a stand-alone piece of software that the users have installed on their personal computers. An on-line version is under development.

Report Profile	Short Report	Full Report A. Occurrence	Full Report B. Consequences	Full Report C. Response
Accident code	Accident type	Type of accident	Area concerned	Emergency measures
Date, Time	Substances directly involved	Dangerous substances	Affected people	Seveso II duties
Reporting authority	Immediate sources	Source of accident	Ecological harm	Official action taken
Establishment	Suspected causes	Meteorological conditions	Natural heritage loss	Lessons learned
	Immediate effects	Causes	Material loss	Discussion about response
	Emergency measures taken	Discussion about occurrence	Disruption of community life	
	Immediate lessons learned		Discussion of consequences	

Table 1: Description of the information categories used for data collection, structuring and retrieval in MARS.

The Short Report contains information submitted to MARS immediately after a major accident. The Full Report, which is normally submitted after an investigation (sometimes after several years), contains more detailed information. Future MARS enhancements envisaged will be based on improving the user-friendliness of the system in terms of data entry, data analysis and extraction of meaningful information. At the same time it is required to maintain a high quality of the data inserted and to reduce delays in accident reporting, which is addressed through the continuous training and the active involvement of the users, and by making the database available on-line. The database in its current format is split into three sections:

1) Report Profile: identifying the date, time, location etc.
2) Short Report: contains 7 tables of classifications and free-text fields facilitating the input of a description of the event
3) Full Report A, B and C: expands the information in the Short Report using pre-defined selection lists that direct the input and allow for a more statistical-type of analysis to be carried out.

The non-confidential Short Reports are available for searching on-line . The Report Profile and Full Report sections are confidential and only shared between the Member States Competent Authorities and the European Commission.

While the publishing of specific MARS data is restricted due to their confidentiality, some examples to illustrate the types of analyses possible in MARS are presented. Figure 2, for instance, shows a quantitative analysis of the human or organizational causes of the accidents contained in the Full Reports in MARS.

The generic analysis in Figure 2 indicates that in comparison to other management and organisational failures, faulty procedures and equipment/system design are the largest contributors towards the causes of accidents. Inadequate written procedures are widely known to be the principal causes of accidents however there is less awareness of the contribution provided by inadequate or inappropriate design of the plant, equipment or systems.

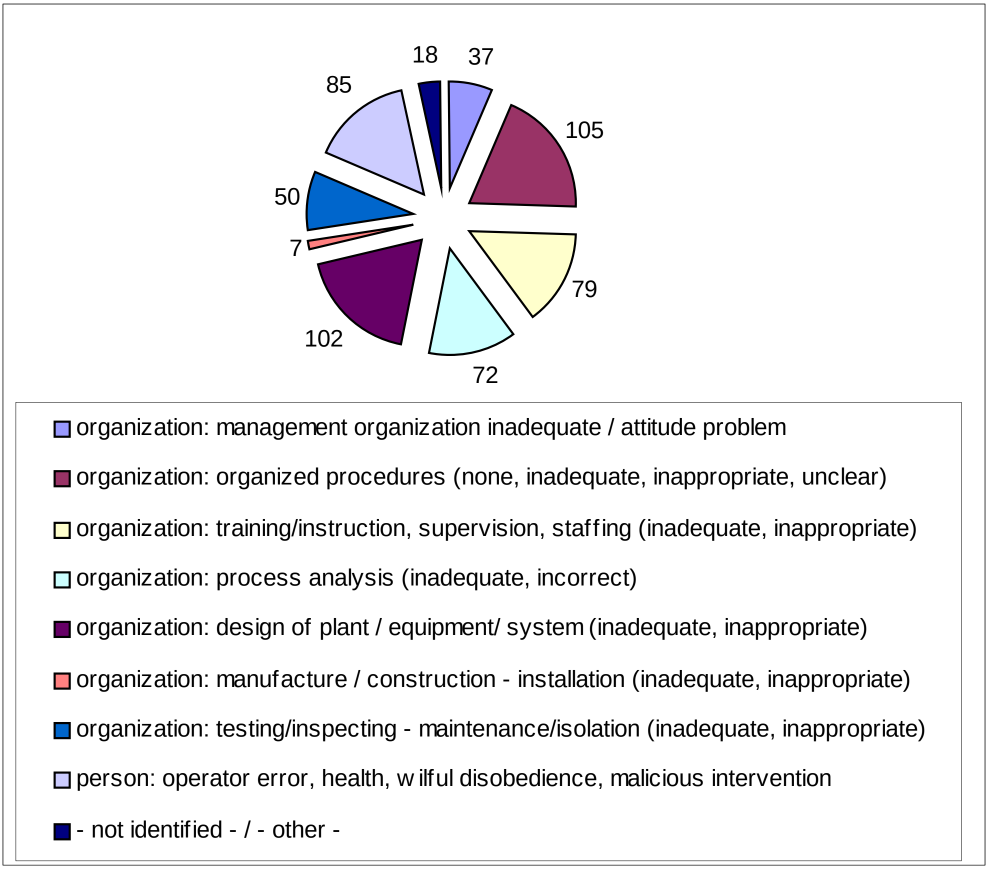

Figure 2: Example of a quantitative analysis of the human and organisational causes of accidents contained in the MARS Full Reports. The numbers in the pie chart refer to the number of accidents as a function of accident cause (total = 232 accidents).

As mentioned previously, a high-quality design of the process and plant is of primary importance and results in an inherent safer plant, therefore it is essential to expand our knowledge in this field and the sharing of information through lessons learning is one way to do this.

Another type of analysis is one that looks at trends within a number of accidents that have common elements. For example an analysis of the runaway reactions that have been reported as major accidents to the MARS database shows us where in the process the most severe accidents have occurred (Tables 2 and 3).

Process area	No. of accidents	Accidents with deceased	Accidents with injured	No. of deceased	No. of injured
Reaction	41	7	25	10	275
Other process areas	22	3	11	4	171
Storage	27	2	15	2	168
Handling & transport	20	1	14	1	148
Maintenance and cleaning	22	12	17	31	100

Table 2. The numbers of deaths, injuries, and number of accidents involving a fatality or and injury in different process areas during runaway reactions.

Process area	Deceased per accident	Injured per accident	% Accidents with deceased	% Accidents with injured
Reaction	0.24	6.71	17	61
Other process areas	0.18	7.77	14	50
Storage	0.07	6.22	7	56
Handling and transport	0.05	7.40	5	70
Maintenance and cleaning	1.41	4.55	55	77

Table 3. Percentages of deaths and injured per accident, as well as the percentage of accidents that generated human injuries.

If the different process areas are examined it is very clear that the most severe accidents occurred during maintenance and cleaning operations. More than half of the accidents studied under this category (55%) resulted in fatalities, and there was an average of 1.41 deaths per accident. The reason for these elevated numbers is mainly that these accidents have taken place during manual maintenance or cleaning operations being performed on or close to the equipment that is involved in the accident. Also, the employees concerned have not been trained in the specific hazards present and are therefore unaware of the risks involved, and without knowledge or training of how to react in the event of an accident, e.g. a release, fire etc.

A third example is an analysis that is directly based on the information contained in the lessons-learned sections of MARS (both in the Short and Full Reports). The 102 records indicating design failure in the first analysis above have been analysed further to extract information on lessons learned regarding the prevention of major accidents where design failure has been a cause. The lessons outputted have been summarised under: Plant/ Equipment and Human/Organisational, so we can clearly see that even though the failure might have been in the design the lessons learned can apply to any and all aspects of the safety management system:

1. Lessons learned for accident prevention - Plant/Equipment:

- Construction: improved plant layout/relocation of vessels, location of monitoring devise in easily accessible areas, better control of seals to prevent or detect leakage, removal of sharp bends etc.
- Design: replacement of equipment to fit purpose, e.g. valve types, change material of construction, installation of isolation valves and catchment tanks, suitability of flanges, redesign of heating/cooling systems etc.
- Process control: installation, relocation or replacement of sensors for better reliability, redundancy of sensors and valves, indicators feeding to control room, better alarms (also visual) and automatic shut-down systems, resizing of vents and safety valves etc.
- Detection/monitoring systems, infra-red sensors for auto-fire-fighting systems, automatic emergency shut-down systems tied into the fire and gas detection systems etc.

2. Lessons learned for accident prevention - Human/Organisational:

- Written Procedures: especially non-normal operating procedures such as inspection, isolation, cleaning, maintenance, shut-down etc.
- Training: more intensive, simulation under abnormal conditions, better understanding of risks etc.
- Enforcement: of existing safety measures, codes of practice, more control over safety equipment and clothing etc.
- Risk assessment: including consequence analysis, safety review: HAZOP, improve storage rules, etc.
- Supervision: restricted access to certain areas, processes only carried out under supervision/authorised at management level, permit to work systems, strict control of contractors, operations requiring permanent attendance etc.
- Maintenance/inspection: programme to be implemented with inspection campaigns, quality assurance to be used, isolation procedures, testing procedures, replacement frequencies, building of records, equipment replacement frequencies etc.
- Chemical analysis: use of alternative materials, discontinue manufacture of product etc.
- Plant Layout: modify layout to reduce risk, improve labelling, improve ventilation of area, etc.
- Emergency planning: evaluation of internal and external plans, procedures for evacuation, alert of rescue services, management crisis team required, etc.

There are also examples of individual accidents whose lessons could apply to a whole industry, e.g. an investigation of an accident in a wholesale and retail storage and distribution facility could produce recommendations to: reduce the size of storage/quantities of substances, control the layout, improve housekeeping, restrict access to the area, improve maintenance procedures, etc. These measures could hypothetically be applied across the industry to improve safety.

Limitations

The methodology for learning lessons outlined in the previous sections is highly dependent on the data reported (or collected). Therefore anything that affects the quality, extent and accuracy of that information influences the final outcome in terms of lessons learned. The data quality can be affected in every step of the methodology from the investigation of an event to the data collection and analysis. This means that minimum standards are required for each step. The availability and accessibility of information is a further restriction in the methodology. External investigations, e.g. by judicial bodies, can be affected by a lack of free-flowing information due to their perceived mandate to assign blame leading to a reluctance to cooperate. In-house investigations may be more thorough, uncovering deeper underlying causes; however this information may then be classified.

Additionally, there are limitations inherent in the development of databases. They are usually set up for a specific purpose or to answer particular questions. However, the field to which they are relevant is constantly evolving, and therefore information that is significant currently may at some point become insignificant, or information that is not being collected currently may actually become indispensable in the future. Consequently, a great deal of effort needs to be invested in the design, application and evolution of databases if they are to be used for lessons learned.

The implementation of lessons learned is a very difficult step, not only to perform but also to monitor. While information can be disseminated far and wide, there is limited influence over what the recipients of that information do with it. There is also a limit to what the recipients can do with the information. If they are, for example, authorities then they can make recommendations to the industry but cannot insist on changes without legislation. Usually they have some modes of communication which enables cooperation with the industry, however, it is difficult to monitor if changes have been made and even more difficult to monitor if they have been successful. This is another reason why providing information to designers is so very important. The designers consider the needs of their business as well as operability and safety requirements when they produce a design for a process. Additional information that has been learned from accidents occurring in the field related to their designs can only be beneficial as it improves their basis of knowledge. A large number of requests for information have been received by the administrator of the MARS database from designers, plant managers, inspectors and safety consultants. Unfortunately in several cases the information is either not detailed enough or may be in the confidential part of the database, although the administrator does his best to provide assistance without compromising the confidentiality of the data. Therefore continuous effort needs to be put into improving the data quality and making the information more openly available.

Outlook and conclusions

A methodology for lessons learning has been proposed above for accidents occurring in the chemical industry, and each stage has been clearly defined. For a comprehensive and proficient system it is important to have a minimum standard in every stage. Emphasis has also been placed on learning lessons in all aspects of the process and plant, but especially in terms of making information available to the designers, since chemical process designs are normally based on "available knowledge". Different types of lessons that can be learned have been described and examples given from the MARS database.

Many accidents occurring within the chemical industry are not occurring for the first time which is why it is important to learn from them. In fact it would be especially beneficial to learn from a smaller accident in order to prevent one with much more severe consequences. Collecting and using information is a vital part of this learning. Additionally the information from several accidents similar in nature allows conclusions to be drawn, which are not always apparent from individual accidents. What is needed is the further development of this work in order to improve the quality of information and to find better ways to use it, such as for monitoring the effectiveness of the safety management system. Furthermore it should be possible to apply some lessons learned from one risk-management field to another. A possible application of this is NATECH events, technological accidents triggered by a preceding natural disaster. This is illustrated by the example of NATECH disasters that occurred during the floods in the Czech Republic in 2002. The flooding may not have been preventable but the ensuing technological accidents could have been, had the lessons learned from flood disaster management in terms of prevention, preparedness and response been directly integrated into the prevention and mitigation of major accidents. A study of the potential impact of floods on certain industry types has been prepared .

The lessons-learning methodology should be further developed by the establishment of a monitoring mechanism that feeds back on the effectiveness of the implementation of the lessons. Unfortunately, this is very difficult to do with the current system based on accidents (investigating, reporting, analysis etc.) since their success, or lack thereof, can only be revealed by the occurrence of another accident.

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Jean Christophe Le Coze

Biography

Role in the project

Writer

Work/Studies today

I have been working as a research and consulting scientist for the French National Institute for Environmental Safety (INERIS) since July 2002.

Background

I was born in 1975 in Brittany, France. I have a background in safety science, with a focus on industrial safety and major hazard prevention. I have some experiences in safety and security management in UK for a private company as well as an experience in major hazard prevention in a SEVESO chemical plant in France. I visited Safety Science Group at Delft University for about a year in 2001, on risk modelling projects. This exchange was an important step toward an appreciation for the need of a multidimensional perspectives on risk assessment and management.

My research interests are currently at the interface of safety engineering and management, human and social sciences as well as epistemology. These researches are directed at major hazard prevention, mainly in the chemical & petrochemical industry, the transport of dangerous goods and tunnels. The themes of these researches include assessment of organisational reliability (or resilience) as well as the organisational nature of (major) accidents. I perform from time to time accident investigations and organisational safety auditing for the authorities or/and the industry. The link between theory and practice is one of the important purposes of my work.

Contribution to this project I would like to share with you some ideas around the problem of complexity in learning from accidents. Discussing about complexity as a philosophical issue provides an interesting background for some important questions such as the limits of models in use for interpreting accidents as well as their values.

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Complexity and learning from accidents

Boris Cyrulnik: I think that in the domain of ideas, we have the choice. We either chose to be a specialist, a very comfortable situation because we need to cumulate more and more information about a more and more precise phenomena: we end up as the dogma says in knowing everything about nothing. Or we decide to be a generalist, namely looking each time in physics, chemistry, biology, psychology, forensic medicine, we end up being specialist in nothing but we have the best opinion on the person that we have in front of us and that we call human. These are two policies of knowledge totally different.

Edgar Morin: It is right, but I reject this idea that we always and inevitably have to be in the alternative, either being a specialist and having a relevant knowledge, acknowledged by the pairs, universities and institutions, or being a generalist and having a flimsy knowledge. This alternative needs precisely to be avoided, which is in fact what is the case for example in science of ecology (…) in general, when you have an object where all the elements are in relation with each other, you call the different specialists involved in this object, while learning and incorporating the key knowledge from their discipline.[1]

There exists a field of epistemology or philosophy[2] of complexity using contemporary scientific developments for questioning our relationship with reality, knowledge and science developments. This field is extremely stimulating and points at ways of thinking about learning from accidents. This paper elaborates on and presents how the epistemology or philosophy of complexity offers an interesting perspective for addressing questions in this field. This paper must be seen as an exploratory paper, using the opportunity of this book's initiative to try to clarify the use of complexity as a core concept. It introduces in a deeper way some ideas already introduced earlier about complexity[3] (Le Coze, 2005). It is important to stress that

1) Boris Cyrulnik, Edgar Morin Dialogue sur la nature humaine , (Dialogue on human nature) Seuil, 2004.

2) It is rather difficult to distinguish clearly epistemology (in the French context epistemology concerns science, and not knowledge in general) and philosophy of science (Soler, 2000). In that article we will use both terms with the idea of talking about these disciplines having a reflexive approach on the developments of scientific concepts, models, theories. The epistemology or philosophy of complexity is one of them.

the philosophical nature of this paper is guided by the concern for a better understanding of the problem of complexity in learning from accident (but also safety), and is not carried out without strong current practical purposes.

Introduction

Complexity as an epistemological question

The developments of philosophy of complexity as developed for example by Morin, finds its roots in some questions raised after some scientific achievements. As the literature dealing with the status of science has shown it (philosophy of science, history of science, epistemology), some key questions have been raised following (r)evolutions in natural sciences as with relativity, quantum physics[4] but also following the assumption of big bang in cosmology (introducing a history and a singular nature of cosmos) in the course of the 20th century. Earlier, thermodynamics had also created a breach in the deterministic view of the world (especially by questioning the reversibility of time that the Newtonian science implied). Thermodynamics led to further developments as for example in chemistry dealing with dissipative structures (revealing properties of self organisation of matter, out of equilibrium) and chaos theory, both introducing questions regarding the status of determinism and the reversibility of time.

In life sciences, open systems were opposed to the thermodynamic principle of entropy (maximum of disorder) because biological systems generate organisational patterns when "fighting" against entropy (a physical principle known for leading to maximum of disorder, to dispersion). These systems are open to their environment, are organised and have purpose, for which feedback principles are key for understanding their non-linear behaviour, but also introduce a circular causality perspective. They

3)In this previous paper (Le Coze, 2005), I identified and summarised the field of complexity with four main points as four ways of challenging and questionning the realist and positivist view: determinism, decomposition (expressed by the reductionist program and the analytical method), linear causality and the independance of the subject and object. This paper will provide more insights on these four points, and will also compare other approaches of complexity, in different fields than this epistemological one.

4)An introduction of the philosophical and historical investigations regarding science triggered by these scientific (r)evolutions, but not only, is provided by Chalmers (1987).

are therefore opposed to the principle of external causality, by introducing teleology (goal, purpose) and opposed to the principle of decomposition (found in the reductionist perspective and also in the analytical principle). Indeed, decomposing a feedback function makes the phenomena unintelligible. They imply control and command and information (both quantitative theories of information and symbol treatment). These were features also developed in engineering, with cybernetics.

All these developments were made earlier and then in parallel with the principles of self organisation, explaining better the "creative" side of the biological world, but also being the result of emerging features ("the whole is more than the sum of its parts") without external written plan (blue print), or without centralised control dictating behaviours of parts. Emergence was a term introduced for accounting about phenomena for which a reductionist approach is not satisfactory but also for dismissing a vitalist assumption. The systemic approach (rooted in cybernetics and general system theory) and complexity ideas (more rooted in self-organisation) are intrinsically linked. These ideas of systems and self-organisation have been developed in a century where the Darwinian theory of evolution combined with genetics (and the development of molecular biology) into a neo-Darwinian approach of life, flourished in many ways along with concepts of ecology starting with the concept of Umwelt (environment) and then of Ecosystem. All these developments led to the worldview where atoms, cells, organs, brains, animals, humans and societies, are understood as emergence of levels of organisation that can't be deduced and reduced from the levels before, but reveal themselves through self-organisation principles, evolution and historical processes.

In human and social sciences, all these themes obviously echoed and still echo strongly today. These ideas have of course spread (but also were originated for some of them) in the development of cognitive sciences (developed through cybernetics, linguistic, artificial intelligence, neuroscience…), in cognitive psychology but also in anthropology, sociology, sociology of organisations, economy for example but also in philosophy and epistemology, with the field of philosophy of complexity, as developed for example by Morin, in the last 30 years.

Morin is seen as a leading thinker on the matter of philosophy of complexity and his thought is very influential in the contemporary debates in general. The use of his epistemology of complexity (what is also called "complex thinking") serves the purpose of defining appropriate and useful mental frameworks, or method, to think, to organise knowledge and to give some philosophical insights on our nature and the nature of our knowledge. As we will see in this paper, Morin's philosophical and epistemological work has been highly influenced, but not only, by cybernetics, system theory and self-organisation (linked with the key concept of emergence), and these are also major features of the human and social science literature on major accidents.

Complexity, system, self-organisation – emergence of patterns – (major) accidents and safety

Before presenting Morin's ideas on complexity I introduce in this part some developments made on complexity in the field of safety and accidents[5], in order to better distinguish them from what is introduced in this paper, while also using complexity as a central word. Complexity has indeed been discussed in the field of safety for some years, either by cognitive psychologists and cognitive scientists (a more "human factors" perspective) or psycho sociologists, sociologists and political scientists (a more "organisational factors" perspective).

We find in the human factors literature some direct references to complexity, for example in Amalberti (1996) or Leplat (1996). They both draw on similar references from previous works such as Hollnagel (1993), Leplat (1988) and Woods (1988) in Goodstein et al. (1988), or earlier with work from Rasmussen and Lind (1981), based on developments of cognitive psychology and human factors engineering. These works specifically target individual levels because they focus on understanding cognitive underlying patterns for a better approach of human error, or reliability of cognition, with the purpose of assessing risks and/or designing adequate work situations. In doing so, they also address some of the dimensions of the installations and processes, as well as the interfaces but also the context of works of individuals.

Some features of complexity are, according to these works, related to the installations and the processes (e.g. reversibility and predictability of processes, time constraints including feedback delays within processes,

5) It is difficult to distinguish the field of safety and the field of learning from accident, they both interact strongly. The field of safety could be associated with researches based on studying systems in normal situations (either at the psycho -cognitive or organisational levels) and practices looking for preventing accidents. Both fields are intrinsically linked.

etc), the interface (e.g. number and type of variables shown, quality and quantity of feedback provided, number of screens, etc), the individual (e.g. level of expertise of the agent, self-regulation of individual through metacognitive dimensions, number of agents for performing tasks, etc) and the environment of individuals (e.g. type of hierarchical structure, co-ordination and distribution of tasks between agents, etc).

Psycho sociologists and sociologists in the field of safety and accidents have also introduced features of complexity inspired from cybernetics, general system theory or self organisation principles to describe safety issues in organisations. In order to break the image of bureaucratic machines, they have introduced the fact that organisations could be seen as open systems, facing uncertainties (from their technology as much as from their markets) and needing adaptation abilities. Weick (1977) introduced the idea of self-designing organisations, and these principles would also be later found in the developments of the high reliability researchers with for example Rochlin, La Porte and Roberts in 1987 with a "self-designing high reliable systems" principle. Bourrier in 1998, following Landau's ideas (1973), introduced the notion of self-correcting organisation for describing the need for evolving and adaptive features of organisations while managing safety. Perrow of course introduced in 1984 the idea of complexity although it appears that it was in fact, according to his definition, very technologically focused: "complexity are those unfamiliar sequences, unplanned and unexpected sequences, and either not visible or not immediately comprehensible". However, by discussing for example the contradictory requirements of centralisation versus decentralisation within various types of systems, he also introduced a more dynamic dimension.

When we move to the field of accidents, we find an open system perspective, but also self-organisation and emergence, although not defined as such by this author, at the heart of the modelling (or theorising) of Vaughan, with the idea of emergence of a dynamic pattern of construction of meaning (normalisation of deviance, 1996) over the O-ring behaviour following many years of feedbacks on that specific topic at NASA. These patterns consists in 5 steps:

1. Signal of a potential problem arise,
2. Behaviours deviating from a performance norm of safety criterion were treated as a serious sign of danger,
3. Investigation of the evidence,
4. After discussion the deviant behaviours of the joint was often "normalized" – thereby defining parameters for a revised working norm too,

5. The risk could then be judged to be "acceptable" according to the new norm.

There is no written plan that people followed but instead the emergence of a pattern. It emerged from people interacting over the years, in a specific cognitive-social-cultural-historical-political-economical context (NASA's institutional context, NASA's culture of "can do" …) and technological context (the specific behaviour of the technical O ring components).

We also find this idea of emergence of organisational behaviour for Snook (2000), but also from human factors scientists such as Rasmussen (1997), Rasmussen and Svedung (2000), Hollnagel (2004). These authors are interested by an emerging behaviour, although without focusing as much as Vaughan on the idea of collective construction of meaning and sense about a single phenomenon over the years (as with a normalisation of deviance regarding the O-rings behaviour).

Instead, but also because of the nature of the accident that he studied, for Snook (2000), there is an emergence at the global level, generated by individuals, each of them independently self-organising their own tasks around predefined rules and creating a global "practical drift", implying a coordination failure (due to loose coupling between actors and their tasks) leading to the accident. The following pattern is described by Snook this way:

1. An organisation is designed, defining procedures and a tight coordination between activities defined through the formal procedures for the worst case scenario.
2. Actors implement the organisation, but in reality the actors have loosely coupled activities between each other in normal operations, and they slowly drift from rules defined by formal procedure to task based activities.
3. The organisation behaves according to this principle.
4. The organisation fails when the drift creates a "resonance" when drifting activities align with each other.

Emergence of patterns (linked with self-organisation, but also with their historical trajectory, as we will see) seems therefore a key concept for understanding safety and accidents. These patterns could be called "emerging self organised incremental patterns"[6]. Vaughan has recently (2005)

6) We have recently used this concept in an accident investigation for pointing out some local but also more global self-organised incremental patterns, combining themselves, undetected by the organisation, and leading toward a weakening of the organisation in terms of major hazard prevention.

used the idea of "slippery slope" for defining with an image or metaphor[7] the type of pattern that she is thinking of when dealing with major accidents and organisational dynamic. The challenge is therefore today, from the "practical drift" of Snook (2000), to the "Normalisation of Deviance" of Vaughan (1996), through the 'incubation period" of Turner (1978), from the type of "behaviour towards accidents" of Rasmussen (1997), to understand the conditions (which are cognitive-social-cultural-political-economical[8]) of the emergence of these accidental patterns, in order to prevent them.

This short presentation on complexity in works from the safety and accident fields at micro-meso-macro levels[9], introducing open systems, self-organisation properties, patterns and emergence, brings us now to what Morin did with these concepts in his epistemological and philosophical work on complexity.

System, self organisation and epistemology of complexity

System and self-organisation (emergence) are powerful concepts that are thus at the core of the work of Morin and his "complex thinking", and also, early, at the core of the complexity ideas in general (e.g. from natural sciences, Prigogine 1968, or in biology and cognition with Maturana & Varela, 1972, Von Foerster, 1974 also Atlan, 1974,) where Morin has been

7) Metaphors or analogies more anchored in the natural sciences have already been used for giving some images of what a major accident "could be". Rasmussen (1997) suggested using the Brownian movement to stress the exploratory dimension of individuals within organisation as a source of risk. More recently Hollnagel (2004, 2006) has used the resonance phenomenon as a source of analogy for facilitating a type of understanding related to organisations behaviours leading to accident. We will come back to that imaginative side of knowledge development later in the paper.

8) Each of these dimensions should be considered before concluding on the predominance of one over the others (it is often tempting to conclude quickly that accidents are mostly due to economical constraints). Given that companies always try to make business and to reduce costs, there will always be economical dimensions behind accidents; however it would be reducing the problem to conclude simply like this, as other companies do not have accidents although producing under economical pressure. I will come back on this reductionist dimension.

9) Large technical systems (Gras, 1993) could be located at a macro level. Gras (1993) suggested a hierarchy of complexity between plants and large technical system (that can also be defined as networks), the latter consisting in the environment of the former. Organisation such as NASA or multi layered civil/military organisations could however not be seen as simple plants, but rather closer to large technical system. This large technical system perspective can be found in Auerswald et al. (2006) when dealing with global safety and security issues at several levels: infrastructure, organisations, networks, markets (insurance) and public policiy.

looking at, for his own developments[10]. The "complex thinking" of Morin is however a very atypical kind of thinking that can sometimes meet difficulties in being understood as it doesn't fall into any categories of today's academically established, but also fragmented, knowledge.

The ideas generated in the several books of "La méthode" (from -1977 to 2004[11]) are therefore not standing very easily in any discipline (Morin has indeed produced in several fields such as anthropology, sociology, philosophy, epistemology, politics, which makes it either repulsive or either very attractive (especially attractive for those who believe that reality does not know scientific boundaries[12], believe that meta-models or meta theories are not to be found for tomorrow and that interdisciplinarity is a key process for treating multidimensional problems).

It is an extremely stimulating thought and gives strong scientific strategies for thinking prevention, research and learning from accidents, but not only for "thinking it" in a common sense, as we don't need, for instance in the field of major hazard, the powerful intellectual work of Morin to realise that we have to put together engineers, psychologist, sociologist or economists to work out the patterns leading toward accidents[13]. It is rather because Morin tackled the epistemological question of our knowledge about phenomena, from the physical, the biological and the anthropo-

10) It is interesting to note that Morin's developments are therefore quite contemporary to the creation of the Santa Fe institute in 1984 in the U.S. This institute is dedicated specifically to the study of complexity in physicical, biological, ecological, cognitive, social, economical systems. A presentation of complexity from one of the funder of this Institute can be found in Gell Man (1995). This author introduces many of the important concepts from the field of complexity as we will see in this paper (order/disorder, information, emergence of complex adaptive systems, the issue of reductionism in science development, the nature of scientific developments, the nature/culture relationship, etc.). Morin has however insisted on the epistemological dimension of his work, by distinguishing what he has called, with a reference with relativity theory, a restricted complexity from a general complexity (Morin, 2007).

11) In this paper, we will only use the 4 first volumes of Morin's work (1977-1991), but two more have been release in 2001 and 2004.

12) As Von Foerster (1995) stated it when questioned about his transdisciplinary background: "I don't know where my expertise is; my expertise is no disciplines. I would recommend the dropping of disciplinarity wherever one can. Disciplines are an outgrowth of academia. In academia you appoint somebody and then in order to give him a name he must be a historian, a physicist, a chemist, a biologist, a biophysicist; he has to have a name. Here is a human being: Joe Smith -- he suddenly has a label around the neck: biophysicist. Now he has to live up to that label and push away everything that is not biophysics; otherwise people will doubt that he is a biophysicist. If he's talking to somebody about astronomy, they will say, "I don't know, you are not talking about your area of competence, you're talking about astronomy, and there is the department of astronomy, those are the people over there," and things of that sort. Disciplines are an after effect of the "institutional situation", interview available at http://www.stanford.edu/group/SHR/4-2/text/interviewvonf.html

sociological views and tried to produce some ideas and concepts of organisation of knowledge for coping with the complexity of reality that his work is valuable. Le Moigne (1977 then 1999, 2001, 2002, 2003) has actively[14] used Morin's work to define a constructivist approach of knowledge, a constructivist epistemology, following a tradition of works such as Piaget (1970) and Simon (1996), leading to a circular representation of science and justifying the status of interdisciplinary researches. A presentation of the constructivist epistemology is also available in Glasersfeld (1995).

The two next parts attempt to introduce the principles of Morin's "complex thinking" (this presentation must however really be understood as an attempt but also as what I was able to understand and to extract from Morin's work).

Essentially, it could be said that two key principles are important to be understood for getting into his work, which are the concepts of emergence and the value of science[15]. Emergence (linked today with principles of self-organisation) has already been introduced in this paper. It implies that although organisational levels are not deductively understandable from the analysis of the levels before, there is however a continuum between all of them (from the physical, biological and anthropo sociological one) from which human, societies to knowledge (concepts, models, theories, ideologies) are, through some sorts of evolutionary (from physics to biology) and historical (societies) processes, the products. But this bottom up (upward) vision of emergence needs to be also thought in a top down (downward) perspective, in order to close the loop. Indeed, how could we see the world

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13) Turner for example already stated these needs for investigating disasters in 1978 " The study of the nature and origins of disasters is the kind of inquiry which is naturally a multidisciplinary one and co-operation between psychologists and sociologists, epidemiologist, engineers and managers is needed to understand the complicated relationship between different kinds and levels of event which lead to the development of disasters", and this has been done early after accident, following for example the Three Mile Island accident by putting together various human and social scientists, (Sills et al, 1982) but also today very recently, following the Columbia accident, with a book released in 2005 (Starbuck and Farjoun, 2005). It is interesting to mention Turner and Morin together in this paper. In the end of the 70's, these two authors were respectively, in disaster study and philosophy, two pioneers.

14) The website www.mcxapc.org dealing with the modelling of complexity is very active in that respect and freely provides a rich documentation on epistemology of complexity and the constructivist perspective.

15) These two themes were respectively the subject s of two special issues of a scientific journal in France ("l'énigme de l'émergence", "the enigma of emergence" 07/2005 and "Les valeurs de la science" "the values of science", 10/2005 from "Science et Avenir"). It is quite interesting to see that these are two central ideas that Morin articulates into his "complex thinking".

independently of our "human way" of looking at it? How could we see the world as independent observers? The theme of the value of science is about the status of objectivity that is defended in scientific developments (and that is the positivist position), and our relationship with reality. Do we co-create the world when interacting with it? If yes, then do we have to address the situation of the observer? How do we do so?

It appears that Morin's "complex thinking" is consequently trying to find a way between some traditional oppositions of:

(1) nature and culture[16]- addressing the relationship linking the physical, biological and anthropo sociological levels.

(2) the subject (the observer) and the object (the observed) - addressing the value of science (or the "subjective" side of the scientific adventure, in order to elaborate on the possibilities but also limits of objectivity)

The basic principles is consequently, to overcome these traditional oppositions and that we must understand our reality through its physical, biological and anthropo sociological dimensions, without having one that would be dominating the other, or reducing the others to their "truth", such as saying that everything is physical (physicalism), that everything is biological (biologism) or that everything is anthropo-sociological *(anthropo-sociologism)*[17]. A way of representing this is to represent graphically this

16) A first attempt to link the emergence of our human culture (that led to today's societies) with our natural side is found in "le paradime perdu: la nature humaine" (1973) which was a precursor of Morin's work on his research for a method of "complex thinking". That first work was the product of a series of conferences organised by Morin and Monod in 1972 in Royaumont, around the theme of "l'unité de l'homme" (The human unity). In his book Morin links works from ethology, prehistory and anthropology through the concept of self-organisation and evolution, in order to show the possibilities of articulating these pieces of works together (from different disciplines) to imagine a possible scenario of a human culture emergence. It is a rupture with the view that humans (and the emergence of culture) can be thought without their biological and animal roots. Thirty years later the ideas contained in the project are still relevant and can be thought with the new advances obtained in various disciplines since, like paleoanthropology, prehistory, genetics, theory of evolution, ethology (Picq, 2005, 2006). One of the problem consequently concerns the way, the method, in which the various disciplines together are articulated. This raises the question of interdisciplinarity and of the method supporting this process.

17) Dupuy (1982) has argued that reductionism and simplistic assumptions would always have the last word over a more complex, such as Morin's "complex thinking", vision of reality. Morin also wonders throughout his work if such a circular approach is possible, but instead of giving up, he makes the attempt and produces very stimulating thoughts. Reductionism is indeed a strong principle expressed in the scientific developments, and has been very successful. This principle looks for the ultimate explanatory concepts that would give a "simple" explanation to a lot of phenomena.

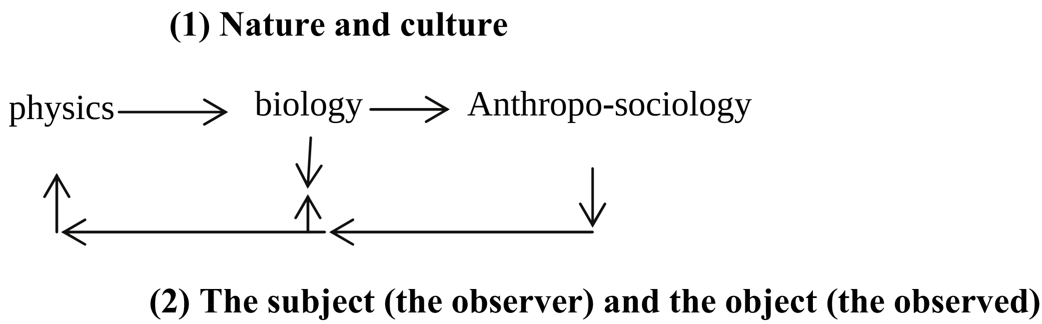

Figure 1: A circular epistemological perspective

circular relationship between the three dimensions (figure 1). We understand that breaking the circle is impossible, we can't think our anthropo-sociological dimensions without their physical and biological roots (nature and culture (1)) but the reverse is also true that we can't think of physics or biology independently of our anthropo-sociological point of view but also independently of our biological abilities (the subject and the object (2)). The loop is closed. We need to acknowledge this circular relationship and work with it although this leads to admit that we produce a knowledge without fundations[18]. A principle that is strongly at odd with our intuitive experience of the world.

Thinking our world is therefore about thinking the three together, but in a way that is consistent, through principles that link these levels in a circular relationship. Complexity, and "complex thinking", is found at the heart of this principle. Morin's research strategy has been therefore to look at the key scientific developments of science of nature and science of life to question our human and social "nature", our physical dimension, and "life", our

Example of ultimate concepts are atoms, neurones, genes, pulsions… Besnier (2005, 2006) distinguishes between a methodological and an ontological (a more metaphysical) reductionism. An example of ontological reductionism statement by a scientist is found is Wilson's work (the father of the sociobiology) on "Consilience" (Wilson, 1998): "the love of complexity without reductionism makes art, the love of complexity with reductionism makes science (…) its strong form is total consilience, which holds that nature is organized by simple universal laws of physics to which all other laws and principle can eventually be reduced". A metaphysical statement acknowledging the emergencies of levels of organisations does not systematically subscribe to such an ontological reductionism program. Morin's work is an example of such a non reductionist philosophical position. His strategy consists in articulating levels rather than looking for reducing them to one principle. This is therefore a different strategy than the "Unity of science" such as it was promoted by the Vienna Circle developments (Jacob, 1980).

18) We see now why these developments fit a constructivist epistemology: there's nothing out of our human (which is physical, biological and anthropo sociological) way of experiencing the world and that is rationaly (empirically) "reachable".

biological dimension. His thoughts are contained in the two first volumes[19] of "La méthode". His research then led him to consider the various works from many fields tackling the question of the possibilities of knowledge. These developments are contained in the third and fourth volumes. The next parts attempt to introduce some of the ideas from these (this presentation can't escape the linear presentation although some of the sources used for each volumes are present in all of them).

The physical and biological dimensions of the living

Some key scientific ideas of our contemporary world: inputs from physics and biology

Thus, in a dialogue between philosophy and science, in the two first volumes of "La méthode" (1977, 1981), to which we could add "Sociologie" (1994, second edition) Morin put together a lot of material from science of nature and science of life. His approach is a circular one, starting with the physical to the biological nature of human and societies. Here are some of these (this is not a comprehensive list[20]):

- Cosmos studies and new trends (big bang following Hubble's discoveries of an expansion of the universe[21]),
- First and second thermodynamics (the dissipative structures and the philosophical discussions from Prigogine…),
- Micro-physics (quantum physics and philosophical discussions from Heinsenberg, Bohr…),
- Cybernetics and system theory (and epistemological discussions from Bertalanffy, Wiener, Von Foerster, Bateson…),
- Self-organisation, recursivity and self-production (autopoësis), emergence and principles of "order out of noise" (with epistemological discussion from Von Foerster, Maturana, Varela, Atlan...),

19) The nature of nature (1977) and The life of life (1981).

20) In this part and the next part some authors will be mentionned as important and "most popular" authors in the field. There are no references for these authors in this paper. They are indications of the often quoted ones throughout Morin's developments. They are only indications, related to my knowldege of the authors in the fields that he explores and that I have understood as being influential, first in their domains, and then in Morin's developments. The list in itself provides some indications for the reader.

21) In a recent dialogue (2003), between Morin and Cassé, an astrophysician, some of the ideas about our universe and on the cosmos extracted from the first Volume of "la méthode" are discussed.

- Evolutionnary theory (Darwinian, neo darwinian developments – from articulations with genetics – discussions from Dobshanzky, Mayr, Waddington, Watson, Crick, Monod, Jacob, Dawkins...),
- Ecology and Umwlet (Von Uexküll...) and Ecosystem (development of Tansley...),
- Ethology (Goodman...), sociobiology (Wilson...),

We see that Morin has been looking at some main scientific developments of science in various fields throughout the Twentieth century for exploring our natural and biological roots.

Concepts extracted from "the nature of nature": the physical roots

All these insights are discussed and articulated to produce a number of principles such as (from the volume 1):

- The presence of order/disorder/interaction/organisation as an underlying transdisciplinary concept of emergence of our world (instead of a strict principle of order but also instead of a strict principle of deterministic laws[22] and instead of matter as a elementary unit, the last point stressing the importance of patterns over elements). This principle is found at the physical, biological (developed in the second volume) and anthropo-sociological levels. It accounts for the possibility of transformation and evolution at these three levels.
- Emergence as a principle for understanding the properties of systems

22) Determinism and consequently the search for laws is one feature that has been seen as a foundation of the scientific approach, as Ceruti notices (1994) "particularly during the Nineteenth century, the search for "laws" progressively becomes the way in which the regulating ideal of omniscience becomes normative in the building of human knowledge. The notion of law is interpreted as a fundamental place of description and explanation of phenomena. The discovery of a law gives access to the Archimedean point, a necessary and sufficient condition for the control and exhaustive explanation of phenomena. It allows for both the dissolving of the particular into the general, the predicting of the past and future course of event, and allows us to conceive of time as the simple unfolding of an atemporal necessity. These epistemological schemata took shape in the interpretation of the great successes attained by rational mechanics throughout the course of the 18th century and the beginning of the 19th, and in that attitude we tended to conceive of this science as being paradigmatic of the tasks of scientific explanation in general. Subsequently, even the great scientific events achieved by the emergence of both sciences of evolution and history (whether natural or social) were shaped by an ideal of scientific quality pivoting on this notion of law. The problem thus became that of determining laws of history characterised by the same necessity, invariance, and atemporality as the laws of the physical universe." A recent special issue of the scientific journal "Science et avenir" has discussed the status of history and determinism in science: "l'univers est il sans histoire", "Is the universe without history?" (2006).

that can't be deduced (and reduced) from the parts, but this bottom up (upward) perspective must be understood also in a top down (downward) one, namely that the sum is less than the part. In a retroactive way, the whole limit the variety of the parts.

- A systemic principle to be linked with an ecological vision of the world (developed in the second volume). The systemic principle stresses the fact that any organisational phenomena is embedded and in interaction within other systems (from atoms to consciousness).
- The teleological principle (namely the purpose of the system) for understanding phenomena self –generating their autonomy.
- Recursivity and autopoïesis (although the principle of closure from the autopoïesis theory is thought with a principle of openness) as a common "organisational" feature of the physical, biological and anthroposociological world through the concept of self - producing "machines".
- Openness as a key principle of intelligibility of reality (a concept that has empirical, methodological, theoritical, logical, paradigmatical impacts leading to a complex vision of the world). It leads to the importance of the context.
- A principle of complex causalities (exogenous -endogenous principles of open systems and interactions of systems, so that little cause can have big effects, same cause can have different effects, leading to counter-intuitive effects through feedbacks), which makes emerging patterns not predictable.

Concepts extracted from the "life of life"

In volume two, a certain other number of principles are discussed and articulated from science of life developments (here are some selected ones):

- Oikos/autos and the concept of ecology (environment) and of ecosystem, where the parts (autos) and the whole (oikos) are linked together in a complex relationship of recursivity (parts are the products of the whole but also the producers of the whole in a dialogical relationship).
- A concept of evolution with a discussion of the notions of adaptation and selection within an eco-organisation through the use of self-organisation of eco-systems, and the introduction of order/disorder/interaction/organisation as a principle functioning of eco-systems (and also a principle of variety as a principle of resilience)[23].

23) Kauffman (2003) from the Santa Fe Institute, attempts to combine self-organisation with Darwinian principle of selection, to provide an explanation for evolution.

- A principle of an ecological science[24] as the first "scienca nueva" introducing the importance of the context, the importance of putting together separated disciplines in a systemic approach, the link between nature and culture, and the necessity of a communication of science and the value of science as the future of our world and humanity depends on it.
- The consequences of this general ecological type of thinking are the following concepts: ecology of action[25] (supported by a principle of complex causalities[26] developed in the first volume), ecology of ideas[27], social ecology.
- The genotypic and phenotypic relationship of the living, where both must be thought interacting with each other, and not separately (endogenous-exogenous dynamical type of relationship), and integrating specy (the general) with the individual (the specific).
- The biological nature of the being (from cells to brains), starting with the act of computing, that becomes a "computo ergo sum", this type of perspective is rooted in the idea of cognition as life[28].
- The emergence of three types of entities (and beings): first order (cells) second order (polycellular organisms – such as plants) and third order (societies of polycellular organisms) leading to insects, animals and human societies (from language to technology, to culture and to modern histocial - social, political, economical – societies) . Through this evolutionnary and historical perspectives, he establishes links with our biological nature.
- The presence within the three orders of three issues: specialisation (and diversity), hierarchy (seen as emergence of levels but also as

24) Capra (who was initially a physicist) , have recently used similar sources as Morin (cybernetics, general system theory, self organisation, ecology, quantum physics, dissipative structure, autopoiësis) to reach similar conclusions on the necessity of developing an ecological and systemic type of thinking (Capra, 1996, 2002).

25) The ecology of actions states that, in the anthroposociological world, our actions do not systematically lead to their intended effects, and that they escape our control.

26) The idea of complex causality is also developed by Morin in biology to escape the notion of genetic program, inspired by cybernetics, in order to be able to move towards a more complex vision of biology, towards a vision of a more systemic and self producing dimension of the living. This idea can be seen discussed now while the paradigm of program meet difficulties following the description of the genome (e.g. Fox Keller, 2004, 2006).

27) The ecology of ideas (as also developed for example by Bateson, 1977) concept will be developed in the fourth volume of « la méthode » (1991).

28) See Stewart (1996) for a presentation and the implication of this perspective, "cognition=life", within a constructivist perspective. This theme is developed further by Morin in volume 3.

domination issues) and centralisation (polycentrism, acentrism), although of course being very different within the different orders (cells, plants, animals, humans, societies). Complexity and high complexity differ from the level of specialisation, hierarchy and centralisation.

- All these developments allow for the elaboration of a paradigm of self-eco-re-organisation[29], as a universal principle for understanding the living (including humans and societies). This paradigm indicates that phenomena are self organised, but also eco-dependant (they are always open and embedded in a larger eco system, a milieu) and re organised (they constantly maintain but also transform themselves in a recursive manner).

Thus, with these two first volumes, we see that Morin tackling some strong scientific metaphysical and methodological statements. We comment only three of them that we think very important for our field[30].

First the principle of determinism (see also note 22). By introducing disorder, and by making of disorder an intrinsic part of historical processes at the physical (thermodynamic, new cosmos theories introducing a history of the universe…), the biological (historical evolution) and the anthropo sociological levels (history of anthropo sociological societies), it challenges a strong taken for granted scientific criteria. It indeed questions science about the nature of determinism. Are our observed phenomena deterministic? Why would they be deterministic laws out there for all phenomena? Is determinism not a metaphysical statement rather than a scientific one? More over, if a principle for understanding complex system is consequently, following cybernetic and system approaches, to introduce the purpose of these system (in the biological and anthropo- social worlds), and that, following self organisation, we acknowledge their endogenous autonomy (despite strong exogenous constraints), then a criteria for science is not only to be able to predict (because autonomous entities are not fully predictable), but to produce intelligible models and theories to interpret and to act in the world, without having to use determinism as the supreme condition for a scientific work. It also calls for a humble position towards

29) In fact this is a contraction of the concept of "self-(-geno-pheno-ego)-eco-re-organisation (computational/informational/communicational) that Morin suggests in his book.

30) There were some strong oppositions from some scientists following the developments from the field of complexity such as developed by Morin, but also by others such as Prigogine, or Atlan, and specifically in regards to the status of determinism. It indeed shakes some core metaphysical principles of science.

our ability to control and to master nature, but also to master our own creations (from technology to societies[31]).

Secondly, stating that for understanding the living (including animals and humans) we need to integrate in a paradigmatic sense the self organised, the ecological and the transformative dimensions into a self-eco-re organisational principle, it limits strongly another scientific principle: experimentation. If phenomena are self organised, open and dependant of their ecological milieu and also constantly transform themselves, then it becomes extremely difficult to isolate, to reproduce exactly the conditions of these phenomena, and therefore we need to understand them within their milieu, their context, but also within their historical trajectory[32].

Thirdly, emergent properties can't be reduced from the knowledge of their parts. A reductionist perspective of complex phenomena is therefore not able to give a scientific description of the whole. The levels can be articulated, but can not be reduced to the nature of the level before. There are communications between the levels, but not reduction. Levels must be thought in their systemic relationship with a bottom up (upward) and top down (downward) causation loop.

The constraints and possibilities of knowledge

Some key ideas about knowledge from the third and fourth volumes

After exploring the physical and biological dimensions of the emergence of our human and social nature and life, in the third and fourth volumes of "La méthode", to which we could add the epistemological work of "Science with consciousness" (1990a), Morin explores the possibilities for the emergence of human knowledge. He explores the relationships of our knowledge with reality and the possibilities, limits, constraints and resources of our ability to answer various types of questions, leading to various types of investigations. Similarly with the two first volumes, Morin uses again a

31) This last point leads to the ethical question, a theme developed by Morin in his last volume (Morin, 2004).

32) If this principle feels today intuitively obvious for our societies, following the events of the last century and its associated ideologies (such as the belief in some laws for history), it is interesting to notice that evolution scientists such as Gould (1989) stress the importance of the lack of determinism but also of our inability to reproduce experiments for simulating the biological evolution.

circular approach. This circular approach starts in the third volume from the biological nature of knowledge, to the cognitive through the psychological and anthropological dimensions of knowledge. In the fourth volume, the approach is historical, political, sociological and finally "noological"[33]. Various works are therefore put together, articulated and discussed. Here are some of these works (again, this list is not comprehensive):

- Genetic epistemology of Piaget, approaching knowledge through its biological side,
- Neuro-science insights on knowledge (from Maturana, Varela, Changeux, Edelman …)
- Cognitive science developments (from Simon, Fodor, Putman …)
- Cognitive ethology (with early works such as Griffin …)
- Anthropology (from Levi Strauss, Durand, Cassirer, Castoriadis, Girard...)
- Psychoanalysis (from Freud, Lacan …)
- Epistemological, philosophical and historical works on science (such as of Bachelard, Koyré, Ullmo, Canghuillem, Popper, Kuhn, Lakatos, Farayebend, Hanson, Holton …)
- Sociological works on science (such as Mannheim, Merton, Boudon, Latour, Bloor, Bourdieu, Habermas, Adorno …)
- Logic (from Gödel, Tarski, Russel, Whitehead, Carnap …)
- Philosophical developments about knowledge (from Kant, Husserl, Heidegger, Wittgenstein …)

Concepts extracted

Some important ideas and concepts can be extracted from the discussions and developments contained in these three books[34]:

- The intrinsic difficulty of understanding knowledge because of the communication difficulties between its natural dimension [information, computing, artificial intelligence], its biological dimension [cen-

33) Morin suggests, following ideas from Popper, Bateson, Monod, Dawkins … that, myths, symbols, representations, ideas, theories have their own autonomy, evolving as self organised entities and systems, under evolution and historical principles (although ideas do not come to life). This type of idea has been developed, following Dawkin's book ("The selfish genes", 1976) through the field of "Memetic" (Blackmore, 2006) , although these later developments appear to suggest a strong reductionist perspective (they indeed reduce, as far as I understand it, consciousness, behaviours and the transmission of culture to the replications of memes, some sort of units of information - such as words, music, ideas - that would replicate from brain to brain under similar patterns as the Darwin evolutionary principles). As Dennett (1995), the "Darwinian" philosopher, asserted "the prospect for elaborating a rigorous science of memetics are doubtful, but the concepts provides a valuable perspective from which to investigate the complex relationship between cultural and genetic heritage".

tral nervous system, phylogenesis/ontogenesis of brain], its human and social dimension [linguistic, cognitive psychology, psychologies, psychoanalysis, psycho sociology, cultural anthropology, sociology of culture, sociology of knowledge, of science, history of culture, of beliefs, of ideas, of science], its philosophical side [theory of knowledge], its "in between" science and philosophy dimension [logic, epistemology].

- Action and knowledge must be thought together, and a link is established through the emergence of the computing from the cells (the cells computing is a first level of action and knowledge, helping the cell to survive within its environment through intelligent behaviour) through animals (ethological works with cognitive and empirical fieldworks reveal the strategic intelligence of animals and the relationship of action and knowledge) through humans (reaching the hyper complexity of the human brain and its modularity).
- The cognitive analogical/logical duality and explanation/understanding[35] duality of our relationship with reality, as well as a cognitive duality between a simple/complex approach of reality.
- A strong influence of a great western paradigm, separating a philosophical thought (meant to be reflexive) and a scientific one (meant to be based on observations and experiments)[36], although both can't be simply summarised as such. This great paradigm is also developed by Morin around the traditional oppositions of subject/object, spirit/body, mind/matter, quality/quantity, finality/causality, feeling/reason, freedom/determinism, existence/essence. This separation is also a strong statement of the positivist philosophy, leaving speculations to meta-physics and defining science by its work on "objective" facts.
- Although science is developed under four independent legs (empirism, rationality, verification and imagination[37]), there is however a "sub-

34) As for the previous parts, these are very limited extractions of what these volumes contain!

35) Rather than opposing these main approaches of phenomena ("understanding" for the human and social sciences and "explaining" for the natural sciences), Morin suggests to acknowledge their articulation.

36) This distinction is the result of the dualistic philosophy of Descartes ("res cogitans" – "res extensa"). Although now it is more admitted with the field of complexity that there is no discontinuity between the physical and biological levels, between the brain and the human mind, and therefore no rupture between the object and the subject. Similar conclusions from a different philosophical perspective (pragmatism), challenging the traditional division of science and philosophy, is found in Rorty (1979).

37) Imagination is not always associated with the scientific developments. Indeed, philosophy of science and epistemology with normative purposes distinguished the context of justification from the context of discovery. The context of discovery refer-

jective" side of the scientific "objectivity", hidden for example under paradigms and incommensurability principles (Kuhn, Fayerebend), research programs (Lakatos) but also themata (Holton), which are metaphysical statements, organising preferences and defining some of the values of the scientific works[38]. Morin suggest in that respect to develop a "paradigmatology".

- Knowledge is therefore a product of a biological, cognitive, psychological, historical, sociological, economical and political conditions allowing deviancies and new theories to be generated, tolerated and expressed themselves, to allow new visions. This of course can't be seen as deterministic, there is a principle of endogenous/exogenous process (micro/meso/macro) generating novelties, that can't be predictive in terms of what will be the new scientific ways of looking at the world, and radical changes are always possible.
- There exists systems of ideas: scientific, philosophical, ideological (the last one supported by doctrines) where science is an extension of philosophy and where ideologies and doctrines differ from science and philosophy (both offering the possibilities of debating and critics) as they are not opened and "bio-degradable" (Morin suggests this metaphor as a way of interpreting Popper falsification principle, meaning that the scientific approach attempts to eliminate error), as scientific and philosophical developments are[39].

red to the creative side and the intuition of the individuals that led to the scientific discoveries (or constructions). The context of justification referred to the validity of the theories and models, their logic and coherence, their empirical validity etc, so that criteria for science could also be ensured. Some philosophers and historians of science have argued about this distinction: why would they be distinguished? They are intrinsically linked and the context of discovery represents an important part of the scientific developments, such as historical descriptions of scientific developments show us. Imagination introduces along the deductive and inductive approaches, the abductive one, allowing analogies to be used for building hypotheses. The notion of "fiction" for example emphasises the imaginative side of the scientific activity (a special issue of "science et avenir" have developed on this topic "Les fictions de la sciences" "The fictions of science"). In that line of thoughts, Morin elaborates on the presence within our knowledge of a still existing and influential symbolic/mythologic/magic dimension, that takes its place within a rational/ technological / empirical dimension.

38) As stressed by Ceruti (1994) regarding this point but also regarding the creative and imaginative side of the scientific developments:" Scientific thought appears, then, as being a rather confused mass of ad hoc hypotheses, analogical reasoning, inductive generalisations from experience, and formalizations. It also seems to be composed of themes, or of deeply rooted, uncontrollable metaphysical cores whose unity and consistency turn out to be linked with the practice and individual itinerary of the subject who uses them, even if that particular subject is the scientific community itself".

39) Morin distinguishes between rationality and rationalisation. Rationalisation is the process of framing everything in a theory, without being sensitive anymore to the empirical evidence of the inadequacy of the model or theory. The use of quantification in qualitative domains is sometimes very illustrative of a rationalisation.

- Science must be thought philosophically, epistemologically, but the reverse is also true, philosophy must be thought scientifically. There is not a separation to be created between science and philosophy. Contemporary science developments naturally led to deep philosophical questions (see as an example the philosophical investigations from Einstein, Heinsenberg, Bohr in the fields of relativity and of quantum physics[40]etc).
- A principle of uncertainty about knowledge and reality, and the importance of the awareness about our mistakes and illusions in the process of generating knowledge, based on models that must be understood as mediations between the world and us, not a definite understanding of things, but as evolving and without fundations.

With these three volumes, Morin suggests to reconsider some strong assumptions regarding our ability to access an ontological reality, independent of a cognitive process but also independent of our historical developments. Therefore, one of the strongest scientific principle, namely objectivity needs to be revised for integrating the biological, cognitive, social, cultural nature of this objectivity. The importance of the metaphysical underlying frameworks such as discussed in the works of philosophers and historians of science must be acknowledged, and integrated in scientific developments, to always take into account the observer in his observations[41]. This doesn't imply relativism, a certain type of objectivity does exist and help us to act in the world, but it is a temporary one, we do not reach an ontological world, but we translate successfully our evolving interaction with it.

With these two parts, "the physical and biological dimensions of humanity and societies" and "the possibility of knowledge", we get an idea of how Morin proceeded to close the circular loop (figure 1) in epistemological work on complexity.

We now get back to the field of learning from accident (and safety), to attempt to connect his epistemological developments with the previous works on complexity introduced in this paper.

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40) This is also true today with the cognitive sciences that are developped with support from philosophical investigations (see for example this point discussed in different historical accounts of cognitive sciences, Gardner, 1985, Dupuy, 1999, Varela, 1999).

41) Morin (1994) distinguishes however the observer in natural sciences from the observer in social sciences. While the natural scientist is an observer/designer, the social scientist is a observer/designer/subject, meaning that he can't extract himself from the society in which he belongs for understanding his, or other societies.

Complexity and learning from accidents

This short presentation of some ideas extracted from Morin's work on complexity helps to distinguish it better from other works. We can indeed differentiate five domains where complexity has been introduced and discussed:

1. A technical complexity (e.g. Perrow's developments around the level of coupling and complexity within technical installations could be located at this level), although we understand now that the self organisational, self producing, adaptive nature and order/disorder principle create a rupture between machines and any biological phenomena[42],
2. a work situation complexity at a micro level (e.g. Amalberti, 1996, Leplat, 1996),
3. an organisational complexity at a meso level (e.g. Weick, 1977, Rochlin, La Porte & Roberts, 1987),
4. an organisational, political and economical complexity at a macro levels (e.g. Vaughan, 1996, Snook, 2000), and at the level of large technical systems (Gras, 1993),
5. an epistemological complexity at a scientific and philosophical level (Morin's developments, 1973-1991).

It would be interesting to elaborate more on some of the common conceptual borrowings between these definitions of complexity from these various perspectives. We see for instance the use of principles of order/disorder/interaction/organisation[43], the emergence of patterns from the self-

42) One important influence on Morin has indeed been the Von Neuman statement regarding the difference between the machines and biological phenomena (Morin, 1973) « A car engine is made of components highly checked, but the risks of failure are equal to the sum of the risks of degradation of each of its components (sparkling plug, carburettor), the living machine although made of unreliable components (molecules degrading, cells degenerating) is highly reliable, on the one hand it is able to regenerate, reproduce the components that degenerate, namely to self repair, and on the other hand, it is able to work despite of the local failure, namely to attain its goals by other means, whereas the artificial machine is at maximum capable of assessing the mistake and stop".

43) Moving from the biological (note 43) to the cognitive dimension; disorder, noise, unexpected events are part of the adaptive activity of cognition. It is precisely the ability to integrate disorder, unplanned events and create a new order from it in order to control events that can be seen at the heart of resilience of systems. The lack of understanding of this paradigmatic difference was found in some prevention strategies "Since humans, as unreliable and limited system components, were assumed to degrade what would otherwise be flawless system performance, this paradigm often prescribed automation as a means to safeguard the system from the people in it" (Woods and Hollnagel, 2006). We learned from experience since, about the limit of automation and the importance of the positive influence of people filling the gaps where things were not anticipated, and the need for people able to deal with disorder. This is now

eco-re-organisation principle[44], complex causalities[45] or the importance of imagination[46], a duality of a simple/complex vision of reality[47] and the importance for a non reductionist perspective[48]; very compatible with the nature of safety and accident dynamic.

Instead of looking for the common features between these works in these various domains (this could be done in next developments), we will use in a more "direct" way the main messages from the epistemology of complexity to the learning from accident field.

Historically situated interpretations: an epistemological question

The philosophy of complexity teaches us that our understanding of accidents, similarly as all scientific knowledge is dated. It is historically located in time so that our interpretations will differ from one period to the other, according to the scientific knowledge and the paradigms underlying the interpretations of the events. It has been quite strongly emphasised in

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recognised at the core of the organisational resilience (there is here a link with the imagination dimension, see note 38). However, there is a side effect to the ability to integrate disorder into a coherent picture, it indeed provides the stage for disasters, as Turner and Vaughan both acknowledged.

44) Dekker (2006) introduces the idea of emerging patterns, following the works of Snook and Vaughan, by "the number of variables involved, and their interaction, makes the idea of safety boundaries as probability patterns more appealing: probability patterns that vary in an indeterministic fashion with a huge complex of technological and organisational factors" . These patterns need to be understood in their environment and historical developments.

45) In « System effects, complexity in political and social life », Jervis (1997), quoted recently in Vaughan (2005) and Roberts (2005), offers - through a conceptual framework developed from science of complexity and grounded in empirical data of political events - an illustration of this type of « ecology of action » and complex causalities principle. Complex causalities and ecology of action are indeed similar and fully compatible with the "law" of unintended consequences, in social sciences.

46) Some have indeed developed around the important idea of requisite imagination (Adamski et al, 2003). As much as in science developments, imagination in safety is a valuable ingredient and the lack of it an ingredient for accidents.

47) Psycho cognitive scientists, such as Amalberti (1996), have shown at the individual level, how making "simpler" the complexity of their working situations is a metacognitive strategy used by operators for dealing with their tasks, and having suitable models (explaining and predicting) to perform their specific tasks. Reducing complexity is a key strategy for them. It has strong implication for individual and collective actions. As Weick (1998) noted "In order to act collectively, people adopt simplifying assumptions. Simplification limits the precaution people take and the range of undesired consequences they envision. These simplifications state the stage for surprise".

48) Starbuck put well such a non reductionist perspective (2005), as one of the lessons from the Columbia accident: "Managing organized complexity systematically: The Columbia disaster resulted from complex interactions of technology, policy, history, environment and production pressures, and normal human behavior. Such complexity is not unique to NASA (…) Thus although complexity elicits our curiosity, we should be modest about our ability to comprehend and manage it".

the literature on accidents and safety, of the historical shifts from a more technological, to a human (questioning the relevance of "human error" for understanding accidents, but also questioning the relevance of eliminating errors at a cognitive level) to a more organisational perspective of accidents. The future of the interpretations of accidents might be complemented (or transformed) by more macro level perspective with political interpretations where the states strategies, at a national level in terms of prevention control, shows a bit better how they influence the likelihood of accidents. But new valuable understanding and developments might also come from an understanding of cognition with some developments at a neural level, in the future.

An interdisciplinary domain in needs for articulations: a methodological question

Morin (1990b) illustrates the principles of his development on complexity with several domains of science and shows how some scientific domains evolved as interdisciplinary ones, where articulations between separated knowledge were necessary for creating a broader understanding of phenomena that cut through the knowledge provided by a single discipline[49], such as:

- Ecology science articulating zoology, microbiology, geography, physics, botany.
- Earth science articulating geology, seismology, volcanology, meteorology.
- Prehistory science articulating ecology, genetics, ethology, psychology, mythology, sociology (see note 17).
- History science articulating economy, sociology, anthropology, psychology.
- Cosmology science articulating microphysics, physics, astronomy.

We could add some fields where it appears to be very similar:

- Ergonomics science articulating physiology, computer science, engineering science, psychology, cognitive science, psycho-cognition[50].

49) Vinck (2000) distinguishes four modes of interdisciplinarity: complementarity, circulation, merging and confrontation between disciplines. They would certainly help to better describe the manner in which these fields (or disciplines) introduced here, were combined and evolved.

50) As Leplat (2003) puts it « The domain of ergonomics consists of articulating different disciplinary views taken about a situation and that this articulation, this integration makes emerging a structure and problems that are not those of the disciplines taken individually».

- Child resilience[51] articulating biology, neuroscience, ethology, psychology, sociology

What are the consequences for the field of learning from accident?

It appears quite naturally that the same applies to it: articulations between various fields are necessary for treating accidents as complex phenomena. Anyone who faces an investigation sees that the phenomenon has a global nature, although this global nature is quite hard to conceptually capture through the lenses of just one discipline[52]. It requires articulations from various disciplinary fields such as sociology of organisations, cognitive psychology, system safety, safety management, psycho sociology while being intrinsically historical work, belonging as well to the historical sciences. From the engineering and physical phenomena to the cognitive, social, cultural, political and economical dimensions, accidents must be approached in a global manner and within a historical perspective that requires quite naturally, once understood, a complex thinking type of perspective.

Although the frontiers between these disciplines and works are not always clear because they tackle some similar phenomena but with different scope but also different purposes, they provide some important conceptual supports for interpreting accidents. They do not articulate automatically between each other as for example some strong conceptual and empirical difficulties arise when we jump from some cognitive to more sociological

51) Cyrulnik, who is a scientist in the field of child resilience, and Morin discusses (2003) about their views on human nature, based on their developments. They reach the conclusion of the need for a scientific strategy looking for articulations between fields for approaching complex problems that cut through disciplines. We have discussed the comparison between child resilience and organisational resilience (Le Coze and Capo, 2006).

52) An interesting example of such a multi dimensional approach, and close to the field of learning from accident because of its historical approach is Diamond's book Collapse (2005). This author provides some interpretations of the collapses of some modern and ancient civilisations while using different disciplines such as archeology, climatology, history, paleontology , playnologist (pollen scientists), within an evolutionary perspective.

or political dimensions[53]. We have started (Le Coze, 2005) to put together a research strategy looking at available works and models about safety and accident in cognitive science, psycho-sociology, sociology, management and political perspectives. This approach can be used for accident investigation but also for offering new perspectives of auditing and designing or "engineering" (see Hollnagel et al, 2006) the reliability or resilience of organisation or socio-technical systems (see Lecoze & Dupré, 2006 for some empirical fieldwork and research in this domain).

From the interpretations to implementing actions: the question of the value of the models

However it must be stressed that understanding events through the articulations of several sources is not the end of the learning from accident process. Important developments are required for thinking the transfer and the learning process for the people practically implementing the lessons to be extracted from the interpretations. The question regarding the practicality of the models supporting the interpretations is of fundamental importance. Modellers are not outside the systems that they interpret and their explanations feedback in some ways in the world. They will be used as support for transforming the working situations, and in that respect each individual locating at various positions have various views, interests, understanding etc. It is important therefore to ask about the value of the interpretations in regards to the practical needs of these individuals, if we want the interpretations to be supportive for improvements. In that respect, we started Le Coze (2007) to discuss the relevance of the models used for learning from the organisational side of accidents. We have distinguished the purposes of the modellers investigating, between practitioners, professional investigators and researchers while asking for the need

53) As Bourrier and Laroche (2000) put it in the field of reliability of organisations: « the methodology that we can apply (…) belong to different fields and disciplines (psychology, ergonomics, psycho sociology, sociology, economy, political science, management and law) for which a global education does not exist. The researcher in social sciences does not possess all these skills. It is a major problem because we understand well today that for progressing in organisational risk factors, it is required to have theoretical tools and analysis methods able to encompass and to link the different levels. In his work, Diamonds (1997) introduced specifically this issue "These requirements seem at first to demand a multi-author work. Yet that approach would be doomed from the outset, because the essence of the problem is to develop a unified synthesis. That consideration dictates a single authorship, despite all the difficulties that it poses. Inevitably, that single author will have to sweat copiously in order to assimilate material from many disciplines, and will require guidance from many colleagues". This quotation describes very well the "complex thinking" type of challenge.

to be sensitive to the gaps between these approaches, when moving along a continuum between prescriptive and descriptive purposes and models.

Conclusion

In this paper, we have attempted to introduce the philosophical developments on complexity from Morin[54]. It helped distinguishing them (but also identifying some common references) from other insights on complexity, in safety and accidents, at micro (technological and individual), meso (organisational), macro (organisational, economical and political) levels.

In particular, we have shown that the philosophy of complexity, by discussing the nature/culture and subject/object issues, created a rupture. Some of the traditional views need consequently to be revised: humans can't be thought out of a shaping evolutionary and historical process, and our natural side needs to be articulated with our cultural one. We need to articulate without reducing it our human nature with its physical and biological sides. We have also seen that it questioned objectivity by discussing our ability to reach a reality independently of a biological and cognitive process embedded in a social and historical "ecological" milieu, this last point introducing the value (ethical) dimension of knowledge production.

In the process of exploring these two issues, the philosophy of complexity challenged some strong metaphysical and methodological views on science developments such as determinism, experimentation (by acknowledging the importance of context), linear causalities, reductionism and the ability to reach an independent external reality (importance of the observer). The importance for interdisciplinarity in this process has also

54) We have not discussed in this paper about the limits of Morin's approach. One limit can be mentionned here. There is a risk when being general and trying to cover many disciplines for providing articulations (instead of being regional and specific to one discipline), not to be able to fully grasp the specificity and limits in each of the disciplines and therefore not providing "reliable" outputs. This is the risk of any interdisciplanry, or integrative approach. We find such a statement in Dennett (1995): "I myself do not understand all the science that is relevant to the theories I discuss, but, then, neither do the scientists (without perhaps a few polymath exeptions). Interdisciplinary work has its risks". For example, other philosophy of science works provide a wide range of perspectives across fields (in a similar fashion as Morin's work, going through physics, biology, human and social sciences, cognitive sciences, emergence phenomena etc) but without attempting to articulate them (see for example Andler et al, 2002a, 2002b, with a realist position). The risk is therefore decreased as authors remain in their domains. These two types of work can be seen complementary. Although they are two different strategies, they provide two interesting points of views. Both can be maintained which also means that disciplines are of course necessary but need to communicate through pluri, inter and transdisicplinary approaches.

been stressed, for a better understanding of phenomena that cut through disciplines.

The philosophy of complexity, and "complex thinking" is inspiring and important for the field of learning from accident. Although not at first concerned directly by all the questions developed in the philosophy of complexity[55], accidents should be understood, in a similar fashion (e.g. without reductionism and without the idea of control supported by a deterministic belief), as the results of biological-cognitive-social-cultural-historical-political-economical dynamic processes. Learning from accidents requires therefore a complex approach, for which the "self-eco-re organisational" nature of the incremental patterns leading to them should be detected and prevented in time. Learning from these patterns is therefore a challenging conceptual and empirical task implying the collaboration and articulation of several disciplines together for which the value of the models produced need to be addressed.

55) We might indeed be thinking for example that the nature/culture problem is not directly linked with learning from accident, however, looking at it in a deeper fashion, concepts such as "safety culture" would gain from being explored in regards with the evolutive and historical developments of early societies, from which the specifity of culture emerged. There is indeed a lot of confusion (Hale, 2000) around the use of safety culture, but also on culture itself. This confusion is a result of the fact that theoritically and empirically, culture is a very complex topic (e.g. Lestel, 2003), implying researches from a lot of different fields (see note 17).

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Inge Svedung

Biography

Role in the Project

Supporting professor

Work today

General professor work like lecturing and supervision of candidates. More specific issues for the time being are; planning and development of a master program in societal risk management, preparation of a manual for prevention oriented follow up and participatory learning from child related accidents, evaluation of municipal programs for injury prevention.

Background

Mechanical engineer, chemist, metallurgist, environmental chemist, consultant, senior lecturer in environmental chemistry and technology and in risk management, professor in risk management

Contribution to this project I brought up the idea of an anthology on learning from events by young scientists/scholars with a professional interest in the field of risk management. I have tried to keep a listening and reflective mind during the seminar and I have supervised the final preparation of the book.

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Young authors – Mature perceptions ?

Reflections on outcomes of a collaborative effort

As a concept the word anthology refers to a collection of minor pieces of poetry where minor refers to extent, not perceived quality or value. An anthology on a topic like Learning from Accidents may not fit that description in all respects but it should be a collection of texts, preferably by different authors and with a certain level of quality and relevance. Maybe it is due to such expectations that invitations to participate and contribute to anthologies are most often addressed to senior peers of the craft, but does it have to be like that? Does the garland of papers, as they present themselves in the preceding chapters of this book, demonstrate something else? Do they all justify their presence by adding something to a total, something of relevance and of brilliance in some respect? Has this anthology project, which started out with an expectation to provide just that, succeeded in doing so? And if so, can one identify any explanatory factors behind it. In other words, can young writers present mature perceptions in a field of their interest? And if so, what would the requirements be for that?

In line with the saying that beauty lies in the eye of the beholder, judgements over the literary refinements and the logical brilliance of the different papers should be left to the reader. But one can discuss if the papers form a larger whole by adding different perspectives to the concept of learning from events. To do that one can begin by asking what these perspectives might be and they are legion.

Learning can be seen as a process by which observations are perceived and converted into knowledge by reflection, based on previous general and contextual knowledge. From epistemology we understand that knowledge can be about an external world and seen as being based on objective and rational facts, but that it can also be about an inner world and based on subjective perceptions and interpretations. The former is often referred to as the positivistic way of looking at knowledge as facts in the form of data and theories, the way that dominates technological and natural science. The latter is more dominating within behavioural and sociological science when individual perceptions and social constructs are in focus. This span is explicitly addressed in some of the papers while others demonstrate a more positivistic or technocratic view.

Some of the papers deal with the process of learning from events in terms of different steps such as identification and recognition of them, reporting, selection of events for more detailed investigation, analysis and handling and diffusion of touched up "knowledge". Existing practice regarding such processes and the way they could be evaluated is discussed by a few. Some discuss this process with reference to its role in risk management and to the different requisites of different actors. The system design process and the importence of feed forward of design prerequisites to the operation and maintenance phases and of feedback to design of knowledge extracted from events are discussed.

The concept of learning is also discussed with reference to different levels - the individual, group, organisation and society. And so is the concept of complexity and the role of adaptive behaviour as it can be understood with reference to all these levels.

Some of the papers address the possibility to support and develop learning organisations by using experiences related to a local context for reflective discussions in local group settings. The possibility to use such processes to influence attitudes and renegotiate outspoken and unspoken rules or commitments is also discussed.

Some of the papers are rather sharply demarcated addressing a specific issue explicitly referring to contexts, while others take up a more general and holistic view.

More can be told about the different perspectives, formats and styles applied by the individual authors but what is mentioned above is sufficient to state the variety. Some overlapping between the contributions is inevitable and to some extent a consequence of a common theme, a common point of time and a communicative collaborative effort. But they all contribute and form a richer and more elaborated whole by bringing their individual contributions together.

For the anthology to fulfil the idea of presenting the perceptions of "young authors" the contributors should be young in some respect. When inviting them to participate no strict age criteria were applied. Instead the idea was that they, as regards education, should be anything from master to post-doctor and with some practical experience as regards the theme of the anthology. It should also be mentioned that the practicalities behind the whole effort and the governance of the seminar were managed by a young scholar.

The seminar event as it was managed and performed functioned both as a learning session and a peer review during which three senior researchers were also involved. Though all three of us played a passive role, just raising a few reflective questions, providing general remarks on the way the work proceeded and answering questions directly addressed to us by the contributing authors. The final papers were also peer reviewed by us but with the deliberate intention of not to interfere with the authors' intentions.

So it has been demonstrated that an interesting and rich collection of papers on a specific theme can be accomplished by a group of non-senior but enlightened and ambitious peers if the setting is right. It has been a privilege to have had the opportunity to experience the dynamic collaborative development of the participants' perception of the theme of this anthology and of their individual contributing pieces.

Ann Enander

Biography

Role in the Project

Supporting professor

Work today

I am an associate professor at the Department of leadership and management, National Defence College in Karlstad.

Background

I am a qualified psychologist and PhD in psychology. I began my research interests in the work environment field, studying particularly the effects of physical and toxic stressors in working life. My PhD work concerned the sensory and mental effects of cold on human performance. Since the early 1990s my research activities have concerned human reactions to risk, emergencies and crises.

Contribution to this project

I have brought in experience from research areas such as risk perception, risk communication, behaviour in emergencies and crisis reactions. Methodological issues concerning collection, analysis and interpretation of data on human attitudes and reactions is another area. My hope to learn and be challenged by new ideas has been fulfilled.

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Lessons from the past – tools for the future?

If anyone has harboured illusions that learning from accidents is a simple and well-defined subject then these seven papers will set them straight. Depending on the perspective from which the collection is considered, very different themes may appear as central. As a participant in the seminar I found the range and diversity stimulating. In trying to sum up my reflections it became something of a challenge to find the overall picture. But this is surely one of the clearest messages from this collection, that we do need to constantly view the problems from different angles and integrate various perspectives. As Ana Vetere says, this is a "dynamic, complex and evolving landscape".

From my reading of the papers with the perspective of a behavioural scientist, I would like to highlight just a few themes which seem to me to run through several or all of the papers and which focus on significant issues for future research. One rather implicit theme concerns the incentives and motivating forces involved in learning from accidents, even if none of the papers explicitly lift this issue into the foreground. However, it is clear that the drive motivating people to examine the causes of accidents and to implement the lessons learned is not something that can be taken for granted. Clearly the risk of being blamed and shamed can be a strong incentive for sweeping issues under the mat. Motivating forces deserve attention in all stages of the learning process. What motivates people to investigate and to report from accidents? The subtle differences between seeking to understand causes and seeking to apportion blame are touched on in several of the papers. In order to maintain motivation it is also important that the actors involved see results and get some form of feedback. Anna-Karin Lindberg illustrates this with her example of the inspectors responsible for supervision activities in the municipalities and their need for feedback on the legal outcome of the cases they have worked on.

Learning is one thing, communicating the lessons is quite another. The problems of disseminating information and of reaching the right target groups is recognized in several of the papers, discussing contexts ranging from the broad societal to the specific organizational. Given the dramatic increase in risk-related information in many different areas of society the issue of communication and distribution of information is of primary importance. As Fesil Mushtaq points out: "lessons learned should not only exist in the memory of people because they can be forgotten; where possible they should be incorporated into the memory of systems…" Here he identifies designers as an important target group.

Taken together the papers reflect a world of change and uncertainty. We need theory to describe and analyse these changes, but we also need to learn more about how people actually deal with the uncertainties inherent in their work and lives. There is definitely a need for more empirical work in this area. Kenneth Pettersen's example from aviation shows us technicians maintaining a fine balance between reliance on rules and formal descriptions on the one hand and awareness of the imperfections of knowledge and fundamental uncertainties on the other hand. On a related theme, Elena Beauchamp discusses the importance of "suspension of acquired knowledge" in order to "provide the space to recognize differences and to introduce caution in transferring responses, approaches and solutions from one context to another". She argues convincingly for a holistic approach integrating knowledge from diverse backgrounds, outlining how participatory processes can improve decision-making.

It is hardly possible today to discuss learning from accidents without invoking the concept of safety culture. This concept is at present right at the centre of current media debate in Sweden, after the contents of a confidential report from one of the Swedish nuclear power plants leaked to the press . In many ways the report reads as a parallel collection of examples of phenomena discussed in the present anthology of papers. The report describes a long period of degradation of the safety culture, which reads as a direct example of what Jean-Christophe le Coze describes in his paper as the emergence of accidental patterns, linking concepts such as "practical drift", "normalization of deviance" and the "slippery slope" that can lead organizations further from safe practices and into a danger zone.

According to the same report regarding the nuclear power plant, production goals and "setting a record" have gradually come to take priority over other considerations within this organization. Again, this reads as an echo of the experiences described by Marcus Johansson of how the motto of "safety first!" in an organization can be gradually undermined when it is obvious that in fact priority is always given to production goals rather than safety limits. But Marcus does also offer a possible road back towards a focus on safety issues when he presents ideas regarding learning as a renegotiation of practice. Here accidents, or near-accident incidents, might be used as an impetus for change, drawing on ideas about strengthening of group norms and collective responsibilities among the people involved in the actual practice. The kind of approach he suggests certainly deserves to be developed further and tested. It seems there is no lack of problematic organizations in need of such tools.

What these collected papers of course cannot convey is the atmosphere and tone of the discussions held at the seminar. The meeting of different disciplines and philosophies of science gave rise to stimulating, and sometimes confusing, exchanges. How can we usefully address the complexities described by social scientists? Are we putting too many phenomena under the common hat of "social constructions"? What confidence can we have in the quality of data collected after an accident? Are we paying too little attention to the underlying political forces? Judging from the discussions, many of us are struggling to integrate a social constructionist perspective into our thinking without "losing touch" with reality. The way we think about risks and accidents may be constructions, but the events themselves are real and with painfully real consequences. Lupton gives a useful map over different positions along a continuum ranging from the strictly realist (risk as an objective hazard, threat or danger that exists and can be measured independently of social and cultural processes, but may be distorted or biased through social and cultural frameworks of interpretation) to the strong constructionist (nothing is a risk in itself – what we understand to be a "risk" or hazard, threat or danger is a product of historically, socially and politically contingent "ways of seeing"). This fundamental debate is reflected in the contributions, and particularly in the discussions held at the seminar.

Looking at society and seeing the same mistakes being repeated over and over again, and familiar accident scenarios recurring, one might easily grow pessimistic about the possibilities for learning from accidents. Despite the difficulties inherent in this theme, still these contributions seem to me to convey a note of optimism. They emphasize the possibilities of new ways of viewing the world, and put forward ideas about how different principles could be harnessed to develop useful tools. These tools range from methods to investigate accidents and organize the information in useful ways to strategies for changing mindsets and promoting better decisions. Together they tend to point towards challenges for the future rather than dwelling on problems of the past.

A group of young scientists active in the field of safety science and more specific in learning from events have in a common effort contributed to this Anthology. The process behind is described in an opening chapter followed by the individual contributions together with short presentations of the corresponding authors. As a sum up some reflections on the outcome of the process by the more senior researchers engaged are presented. The authors hold the copyright of their individual contributing chapters.

The Anthology emanates from an initiative taken by the National Centre for Learning from Incidents and Accidents (NCO), a division within The Swedish Rescue Services Agency. NCO also arranged the process and the practicalities around it.

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