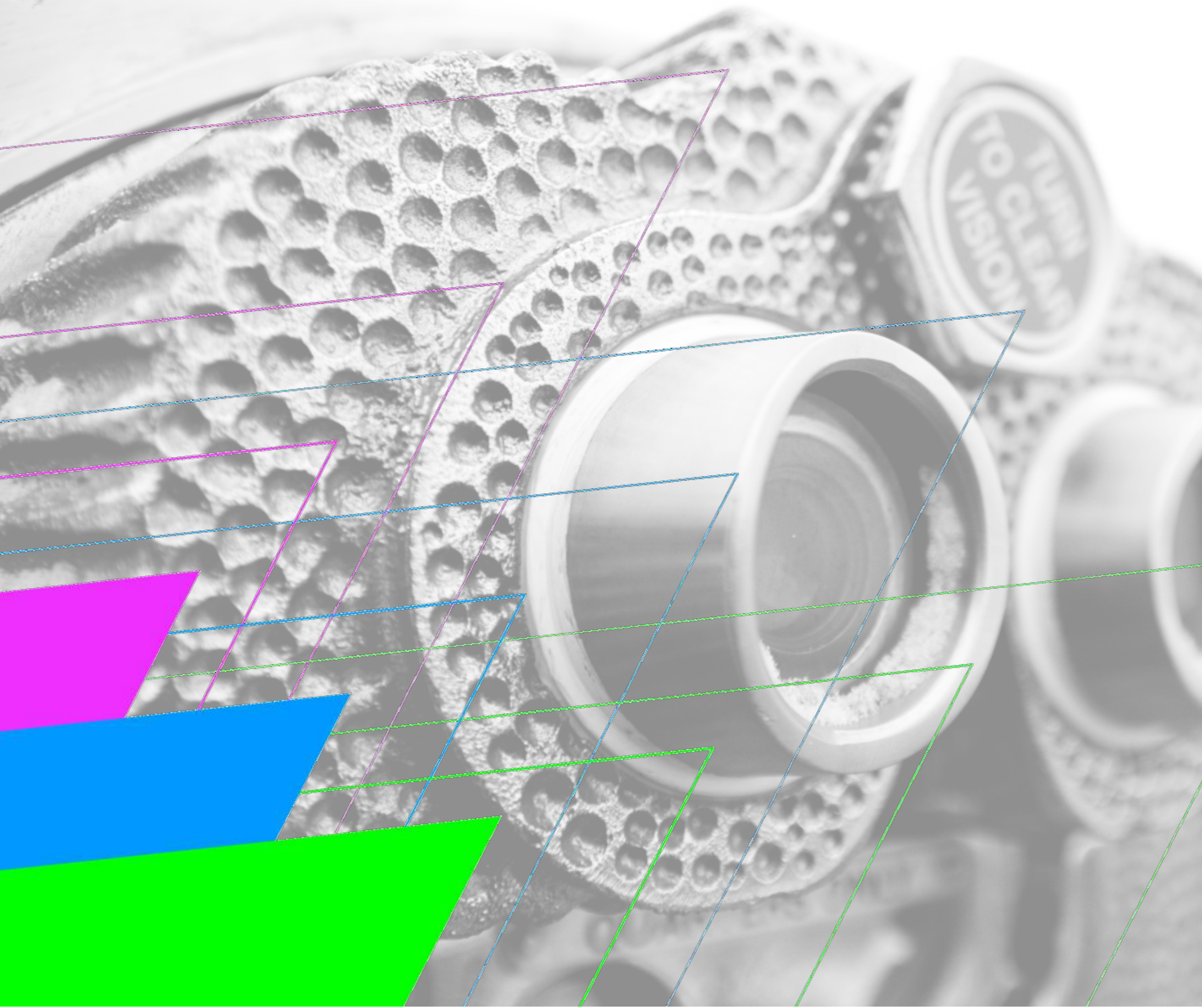
Enhancing Safety: The Challenge of Foresight

ESReDA Project Group *Foresight in Safety*

Chapter 1

Theories, traditions, and challenges — A new approach



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1 Theories, traditions, and challenges – A new approach

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Executive summary

In this chapter we explore historical relations between safety, foresight, innovation, and policymaking. We also look at how these relations got lost over the last two decades and how they can be restored. Socio-economic drivers, political philosophies, and social values shape foresight in safety. We have taken a top-down perspective to gain insights into these higher order forces.

The chapter outlines the historical background of foresight, reviews the evolution of foresight-theories, and lists the methods used. The time concept in foresight, foresight traditions, and futures research is described and analysed, as are the relationships between safety, investigations, and the modern system approach. The strategic triangle and resilience are also discussed.

Among the recurrent themes discussed is the role of safety in legacy and innovative systems, the full information paradigm in combining feedback and feed-forward control of safety, and the role of resilience engineering.

A discussion on the 'Foresight in a world at risk', illustrated by the 2020 coronavirus pandemic, stresses the need to be organised in order to safeguard resilience. In summary: sense and learn from the past, make-sense and act in the present, and prepare for the unexpected future.

The approach towards a safety foresight methodology and challenges is outlined, and examples given of foresight implementation in areas such as management, education, and learning.

Finally, we suggest integrating several notions as building blocks for a multidisciplinary activity in the domain of safety and foresight. Recommendations are made for a new holistic safety management based on feed-forward as well as on feedback information and insights.

1.1 Introduction

1.1.1 Combining foresight and safety

During the work of various ESReDA project groups on safety, the topic has been shifting. Starting in 1993 with exploring the early phases of the investigation process – as data collection and guidelines for investigation of accidents - to later phases like dynamic learning as the follow-up from accident investigations. The focus on foresight represents a shift from reactive to proactive approaches. What are the origins of foresight as a pro-active notion, and how are they related to safety?

In this chapter we explore historical relations between safety, foresight, innovation, and policymaking. We also look at how these relations got lost over the last two decades and how they can be restored. Socio-economic drivers, political philosophies, and social values shape foresight in safety. We have taken a top-down perspective to gain insights into these higher order forces.

The chapter outlines the historical background of foresight, reviews the evolution of foresight-theories, and lists the methods used. The time concept in foresight, foresight traditions, and futures research is described and analysed, as are the relationships between safety, investigations, and the modern system approach. The strategic triangle and resilience are also discussed.

1.1.2 Foresight, how it began

In addressing the concept of foresight from a historical perspective, Martin (2010) clarifies various early interpretations and perspectives, originating from the Science, Technology and Society (STS) debates in the 1970's. These STS debates aimed to foreseeable effects of innovations to societal developments and their problem-solving potential for practical problems. Such innovations affected a large-scale introduction of Nuclear Power Plants (NPP), Electronic Highway and DNA technology. Disasters in these areas were deemed to have unacceptable consequences and should be addressed proactively in order to make them socially acceptable.

According to Martin (2010) foresight is defined as:

"a process by which one comes to a fuller understanding of the forces shaping the long-term future which should be taken into account in policy formation, planning

and decision making. By clarifying input assumptions, one can come to a prediction of outputs which can be justified scientifically."

In this definition, the goal of foresight is to systematically survey all paths that could be developed and identify what options or alternatives are open. This process explicitly does not restrict itself to preferential options from a single actor perspective but covers all options from an evidence-based perspective. From this point of view, decisions of today create the future by taking actions (Martin 2010). Such foresight is based on an understanding of interrelations between science, technology, and society. It should help to stimulate public discussion of desirable futures and of the role of government in such futures (Steed and Tiffin 1986).

During its development, foresight has covered three domains of interest:

- technological innovations and their transition processes by industrial initiatives;
- policy making, assessing the impact of decisions and actions of governance control;
- foreseeable safety consequences of new technologies revealed by case-based learning.

1.1.3 A sensitivity to overarching philosophies

Projects on foresight were initiated in several highly industrialised countries: the UK, US, Canada, Japan, France, Germany, the Netherlands, and Australia. Martin observes that the development of foresight was dominated by different countries' political and socio-economic philosophy (Martin 2010).

In the USA and UK, the Reagan and Thatcherite 'New Economy' intended to 'roll back the state'. The aim was to reduce governmental responsibilities in selecting preferential priorities for policy making decisions on innovative developments. The selection of winners and prioritising was left to 'the market'. Foresight had no part of their privatisation and deregulation policy. In this political philosophy, there was no need to identify and select scientific and technological priorities. In the UK—and to a lesser extent the US—a convenient framework of scientific notions was developed by social and organisational scientists as Reason, Rasmussen, Perrow and Turner. Safety became 'emergent' and unforeseeable due to 'complexity', while accidents became 'normal' after a period of 'incubation' (Stoop, 2020). This framework disculpated those with governance responsibilities, and masked governmental failure of foresight in safety. It left foresight to those corporate levels and gave them exclusive managerial responsibility for safety and risk control. Within the framework, safety was no longer a societal concern, but became an operational performance indicator at a corporate level, submitted to efficiency/thoroughness trade-off considerations, balanced against other process indicators such as costs and lead-times. To this purpose a toolkit with ALARP (As Low As Reasonably Practicable) criteria for accepting risks and safety cases was developed, in conjunction with Safety Management Systems with quantifiable safety performance indicators.

This neoliberal framework assumed confidence in a proper functioning of such delegated responsibility for safe operations and a fair-trade behaviour of each of the actors with respect to risk avoidance, liability, and expert knowledge (Pupulidy, 2019). The shift in responsibility, from governmental oversight and control to self-regulation in industry, was based on the assumptions that substantive safety knowledge was in the market and that governmental oversight of corporate safety management processes would suffice.

However, unforeseen vulnerabilities in these assumptions emerged over time, culminating in serious concerns about deregulation, privatisation, and a proper functioning of Safety Management Systems (Farrier, 2017; Pupulidy, 2019):

- in disconnecting content from process, a shift occurred from a factual and actual performance control to compliance with standard operating procedures. Regulatory on-site inspections were replaced by functional demands on managerial processes.
- This shift also hampered feedback from anomalies, empirical disclosure of deviations, incidents, and accidents. Lessons learned from safety investigation and recommendations at a sectoral level became detached from corporate Safety Management System input (Farrier 2017). At this corporate level, a new set of performance indicators had to be developed, such as Safety II as the expression of Best Practices and learning from successes.
- Recognition of that a degree of operator variability is normal also indicated differences between Work As Intended - by management - and Work As Done - by operators. This difference caused controversies about the acceptability of deviations and compliance with Operational Excellence (Winters 2017). Issues emerged on liability and accountability, culminating in legislation on Corporate Manslaughter and Corporate Homicide.

- Erosion of operator flexibility in task performance occurred, in particular in conditions deviating from optimal, and in crisis and disaster situations. In aviation, a simultaneous operator training was reduced to operate under standard situations, accommodating a more flexible and cheaper transition between configuration adaptations and software equipment versions in the operating environment. This shift from competence-based operator skills to compliance-based task performance eroded the notion of operator flexibility in dynamic operating environments and conditions to a great extent. It led to several catastrophic accidents. In the aviation and maritime industries, 'Good Airmanship' and 'Good Seamanship' came under pressure.
- A lack of agreement about operator performance, non-compliance with established safety standards, and exclusive managerial control created a stigmatising role as whistle blowers. This count in particular for substantive experts and experienced first line operators in assessing safety critical situations that were beyond control and awareness of corporate management.
- Several catastrophic events demonstrated that the neoliberal framework of delegating responsibilities tends to erode existing barriers and precautionary measures relied-on to prevent disaster. In particular, with the airplane model Boeing 737, disruptive developments were introduced, supported by Next Generation and MAX branding, while their certification was treated as only derivative. A decision-making tool for certification of derivative developments proved to be lacking. The Boeing 737MAX crashes have become the salutary example of unforeseen consequences of deregulation and privatisation of the civil aircraft certification regime with still unforeseeable global consequences for its revision and adaptation.

With the emergence of deficiencies of the neoliberal New Economy philosophy, a next generation of safety management philosophies is under development as a successor of what behavioural scientists called the 'old school of safety thinking'. With the acceptance of deviation as normal - inevitably manifesting itself by emergent properties - the safety debate shifted from the origin of deviations and causes of mishaps towards recovery from such deviations and mitigation of their potentially catastrophic consequences. Most prominent in this 'new school' of thinking at the organisational level is the notion of Resilience Engineering (Woods and Hollnagel, 2006). At the level of governmental oversight, retrospective independent safety investigations were institutionalised under the notion of 'Independent Investigations, a Citizen's Right and Society's Duty' (Van Vollenhoven, 2001).

Since the ability to foresee deviation and taking precautionary measures was denied due to the assumed impenetrable and inherent complexity of socio-technical systems, foresight as a notion was no longer incorporated in this safety debate. This has had far reaching implications for managing the (scientific) knowledge base for enhancing safety in complex socio-technical systems. After a seemingly stable situation of validating assumptions and expectations, these systems seem to have reached their third and final phase of development (Minsky, 1986). In this phase, a distinction between derivative and disruptive adaptations is lacking, while profit-taking is no longer covered by future developments due to a lagging investment in precautionary arrangements and scientific knowledge development (Minsky, 1986; Vincenti, 1990). According to Snowden (2007), such a final phase may trigger a transition from complex systems into chaotic systems. Such a chaotic system potentially creates catastrophic interdependencies due to its reliance on operational feedback.

As deficiencies of the New Economy philosophy become visible, a next generation of safety management philosophies is under development'. Most prominent in this new school of thinking is the notion of Resilience Engineering (Woods and Hollnagel, 2006). Foresight as a notion, however, has yet to be incorporated in this safety debate.

Outside the Anglo-Saxon world, northern European countries have seen the safety and risk debate take a different direction with respect to foresight. Based on the Rhineland governance model (Stoop, De Kroes, and Hale; 2017), the debate adhered to a concept of cooperation and deliberation. Examples of this include the Dutch consensual Polder model and the Scandinavian humanitarian philosophy of Vision Zero. These differences impacted the approach and development of foresight in safety as a societal and strategic value.

In the Netherlands, several major projects were initiated by the government in the public debate on the desirable future and the role of government (Martin 2010). The emphasis was on forecasting the consequences of policy making with respect to introducing nuclear power, the electronic highway, water management, land use planning and large railway infrastructure projects. Several Parliamentary Inquiries disclosed emergent market failures in realising these projects and invoked the justification of governmental initiatives and interventions in these areas (TCI, 2004; Van Kleef, 2016). To facilitate technological transition strategies, network-based Public Private Partnerships were created. Contractual conditions for risk liability changed from DC (Design and Construct) to DBFMO (Design, Build, Finance, Maintenance and Operations), changing the financial accountability relations and risk management responsibilities between public and private partners in such networks (TCI 2004). Along with these new contracting forms, privatisation and liberalisation became the norm.

This development was in line with EU initiatives on R&D projects in Framework programmes, based on long-term planning, such as the EU Vision 2050. Such major projects were supported by the establishment of R&D institutes similar to the RAND Corporation in the USA, and the creation of research networks between academies, industry, and universities. Educational courses were established, such as a faculty of Technology, Policy and Management at Delft University of Technology. Leading multinationals, such as Philips, Shell, and Unilever, developed in-house methods for innovation and change management in cooperation with academia and research institutes (Berkhout, 2000).

In these developments, safety has competed poorly against other corporate priorities such as environment, sustainability, circular economy, and climate change challenges (TCI 2004). The decay of safety concerns coincided with complacency in government and industrial legacy sectors where safety had achieved an outstanding performance level. Transport, nuclear power, and the process industry were assumed to be Non-Plus Ultra-Safe, leaving room for only marginal safety enhancements at very high costs (Amalberti, 2001).

1.1.4 Two worlds drift apart

Foresight on safety in the abovementioned sectors became disconnected from their technological developments, while the scientific debates on safety shifted from substantive assessments to managing process control, risk perception and risk acceptance standards. Safety was assumed to approach a theoretical asymptote value of 10e-7 which would leave residual risks as highly unlikely and therefore, negligible. Consequently, there was no trigger to explore R&D needs and development in safety investigation methodology beyond accident modelling and Human Factors research. In the New Economy philosophy, process drives out content, market drives out knowledge. Even a question was raised whether safety science was superfluous to existing (social) disciplines or was a science at all (Safety Science 2014).

In the scientific debate on recognition of social sciences in the foresight domain, a wide variety of different terminologies, paradigms and notions emerged (Martin 2010). Simultaneously, a dialectic stall emerged in the safety debates, confronting safety notions and interpretations from a variety of perspectives (Safety Science 2014, Stoop, Hale and De Kroes 2017). The variety in terminology created confusion and controversies in both domains (Martin 2010, Safety Science 2014). As stated by Martin (2010): terminology is vitally important in the social sciences. 'The emergence of a new term often heralds the identification of some new phenomenon, or at least the recognition of an existing phenomenon that, until now, has laid undetected by social scientists. He identifies several threats to coining new and unique phrases: a particular choice of phrasing may either greatly enhance the prospect or ruin the chances of that research having any appreciable impact. It also may create problems in establishing intellectual property claims on intractable problems and cause loss of persuasive arguments to incorporate foresight in a political philosophy. Finally, while allocation a new and unique label may attribute newly discovered phenomena to the reputation of social scientists, it may give rise to priority disputes in their discipline and in such disputed cases, accusations of plagiarism among colleagues and discrediting or rejection of scientific schools of thinking by practitioners (Martin 2010, Zimmermann et al., 2011; Stoop, 2019).

A less virulent consequence of coining phrases is the gradual separation that occurs across scientific disciplines, in particular between engineering design and social sciences, where a 'debate of the deaf' occurred. Due to differences in language, contexts and operating conditions, separations can also occur between various industrial sectors, academic debates and safety investigation practices. Such a separation can be observed with respect to safety between resilience engineering, safety science and the aviation sector, each developing their own reference framework, paradigms, methods, and tools (Zimmermann et al., 2011). A striking example of such a difference across sectors is present between the process industry and aviation, questioning whether there is a distinction or not between process safety, occupational safety, external safety, rescue and emergency safety at a governance or corporate level (Stoop 2019). Such differences also created diverse problem definitions and problem-solving strategies across disciplines and application domains (Martin 2010). Such differences also raise doubts about the extent to which the theories and notions in foresight generalise to the field of safety, and vice versa.

1.1.5 Feedback from reality

Each of these disciplines and domains applied specific approaches, covering impact assessment studies, probabilistic risk assessment and safety management policies. Both legacy sectors and new technologies were submitted to such safety and risk assessments, focusing on perception and acceptance of either occupational safety, process safety, environmental safety, rescue and emergency, recovery and resilience, criticality and vulnerability issues (Van Kleef, 2016). Most of these debates were ad hoc and driven by events. Such managerial assessments considered residual risks. However, risks assessed as more remote than the 10e-7 frequency limit, would be deemed negligible and their potential catastrophic consequences expelled from the equation. Instead of understanding such events, the absence of investigating their nature and context caused ignorance about their complexity and dynamics. Devils in the details were not scrutinised. Furthermore, their social impact, public perception and acceptance were not considered in the decision making on their acceptability. This managerial safety and risk philosophy created a category of very low frequency/catastrophic consequence events which were not foreseen to their full extent but were nonetheless considered 'normal' (Perrow 1999). Only in the 1990's, after a series of iconic disasters, did their criticality and social impact became the subject of academic interest.

The 1990-2000 era revealed complacency in the governmental oversight of this category of catastrophic events; concerns were raised about foreseeability and acceptability. Notions of prevention, proaction, recovery, resilience and foresight became buzzwords in the academic and policy making debate. Safety 2 was coined as a proactive, complimentary 'new school' notion for the reactive 'old school' of safety 1, accompanied with a plea for a paradigm shift in safety thinking (Safety Science 2014, Stoop, De Kroes and Hale 2017).

At the same time, several iconic accidents in the 1990-2000 era in the high-tech industries of various industrialised countries raised concerns about the predictability and societal control over major safety and risk events. The main examples are noted, below.

- Several major air crashes occurred shortly after one another in the Netherlands: Bijlmer Boeing 747 (1992), Texel DC3 (1996), City Hopper, Schiphol (1994), Eindhoven Hercules (1996), while international TWA 800 (1996) and Concorde (2000) crashes shook public confidence in aviation.
- In the railways, train crashes occurred in the UK at Clapham Junction (1988), Channel Tunnel (1996), Ladbroke Grove (1999), Hatfield (2000), in the Netherlands near Hoofddorp (1992), in Germany at Eschede (1998), and in Norway (2000).
- Passenger ferries capsized in 1987 (Herald of Free Enterprise) and 1994 (Estonia), while severe oil spills occurred with the Exxon Valdez (1989), Braer (1993), Sea Empress (1996) and Erica (1999)
- Nightclub fires with large numbers of casualties occurred in Sweden (Gothenburg 1998) and the Netherlands (Volendam, 2000), while a firework explosion in Enschede (2000) and a nitrate explosion in Toulouse (2001) destroyed a complete neighbourhood
- In the process industry, in 1976 the Seveso disaster and in 1984 the Bhopal disaster occurred, while Harrisburg (1979) and Chernobyl (1986) disrupted the nuclear energy sector.

These accidents became iconic because they served as wake-up calls and triggers for change in these industries and in the prevention of such events. Learning from accidents to prevent recurrence of similar events became a political topic in order to restore public confidence in industrial sectors and regain governance control over disastrous events and their aftermaths. Recovery from industrial disaster became relevant, while the Hurricane Katrina flooding stimulated resilience engineering thinking in the public domain. In addition to already existing subjects, new policy domains were explored such as rescue and emergency, public governance and oversight, prevention and proaction. In 1997 the Swedish Riksdag (Parliament) adopted the concept of Vision Zero; no fatalities in road safety as a risk acceptance policy making goal, while several countries took initiatives for establishing independent safety investigation agencies. All across Europe, investigation agencies broadened their traditional perspective from the transport sector to other sectors of industry and public governance on either a single mode or multimodal and multisectoral basis. In 1993, the community of independent national transport safety boards established an international network, the ITSA (International Transportation Safety Association). This sharing of experiences and learning from each other by feedback from reality originated from their experiences with case based and evidence-based learning. Due to a series of major disasters in various domains, the Netherlands took a leading role in this development. Independent safety investigations became a governance role model for industrialised countries across the world under the motto of 'Independent Safety Investigations, a Citizens' Right and Societies' Duty' (Van Vollenhoven, 2001). Safety investigations into specific events provided the necessary feedback for prevention and proaction. This investigative approach was acknowledged by the European Union (EU) by issuing a series of Directives, institutionalising independent safety investigation agencies in various sectors and domains. Foresight based on feedback from reality provides a powerful, plausible, and credible retrospective approach. However, prospective foresight, based on theoretical grounds and scientific methods, was not incorporated in this knowledge network development.

1.1.6 Three driving forces

This chapter identifies three higher order driving forces that govern relations between foresight and safety. These offer a means for long term development. Each of these three forces is embedded in a specific context of the science, technology, and society (STS) debate:

- in societal policy making, foresight reflects the acceptability and sustainability of the consequences of new technologies and their social benefits;
- in technological innovation, foresight in industries assists the change and transition management processes that introduce new industrial developments and deliver their economic benefits; but,
- in the scientific domain, safety and foresight have become separate disciplinary activities, both in feedback learning and in the feed-forward assessment of new technologies.

In conclusion, there seems to be a unique opportunity to re-unite and integrate safety and foresight by combining a feedback and feed-forward perspective on long term future developments.

1.2 Thinking about the future

1.2.1 Five different attitudes to future

Human beings have always been concerned about their place in existence: the past, present, or future. Many have been especially concerned about the future that lay in front of them individually, in front of their families, or in front of their group. Today, we also include the nation, major regions such as EU, and the global community.

An individual's point of view dictates their attitude towards the future. Almost any aspect of belief or identity is pertinent: religious, political, social, economic, demographic, commercial and other variables such as ethnicity, age, gender, status, and sexual orientation. Some general views:

- The future as fear and threat (religion, but as heaven in a new life!)
- The future as happiness and joy (ideology, religion, social engineering)
- The future as unimportant and immaterial (determinism)
- The future as characterised by risks, probabilities, and possibilities (science)
- The future as adaptive and prosperous (technology and socio-technical engineering)

The time horizon may for analytical reasons be divided into short term, middle and long term.

Each of these approaches have been described in religious literature (the Bible), in many philosophical books, in scientific works, in technical papers and books, in novels and poetry, in science fiction, etc. Many conceptions about our future destiny form part of our oral traditions. Famous persons, who have contributed to futuristic thinking, include i.e. Leonardo da Vinci, Jules Verne, H.G. Wells, Herman Kahn, Johan Galtung, Stephen Hawking, Aldous Huxley, Robert Jung, George Orwell, and Alvin Toffler.

Some recent examples of global threats include studies made by OECD, studies concerning opportunities and trends in technology (South by Southwest, 2016) and several climate reports.

Another example which highlights challenges more than threats is Samsung's SmartThings report about Future living. This is an example of a study with a very long-time horizon (a 100 years hence); it deals with the huge implications of the digital revolution on our lifestyles, homes, cities, and countries.

1.2.2 Theories and their scientific background

The scientific approach to foresight dates to the 1950s, with the start of Technology Assessment and Forecasting. Today, modern safety thinking has been elaborated in many directions and is applied to many different subjects. Foresight includes the use of a variety of methods and techniques (Popper 2008 a/b; Jackson

2013; Sager 2017). The specific notion of 'foresight in safety' is analysed and defined in a separate chapter.

The scientific approach labelled as 'foresight' is defined in contrast to another discipline called variously 'future research' or 'futures studies'. 'Future research/futures studies' were often disputed within scientific circles: could such an approach – which was not based on theories and hypotheses and tested against empirical data - be included as 'real scientific research'? Or was it an art? Although a final agreement has yet to be reached, it is clear that the study of futures (possible, probable, or preferable) has neither the traditional characteristics of natural sciences nor the methodology of some social sciences (Selin 2008). However, futures studies are now both an academic branch and a business. The academic use of futures studies can be found in the environmental/climate sector and dedicated research centres, often with scientific programmes. However, far more extensive are the semi-commercial (e.g. think tanks) or purely commercial consultancies offering a widely sought-after, broad repertoire of techniques, such as trend studies/trend analysis.

As a form of futures studies, strategic foresight studies had many early authors and scientists that initiated or anticipated the more systematic and knowledge-based understanding which were established after WWII. The use of strategic foresight studies grew mainly within defence planning and expanded later to the public sector (state/regional innovation), to large regional organisations (such as EU) to the private sector (such as multi-national companies).

1.3 Foresight as an object of research

1.3.1 The time concept in foresight

Safety implies change, and change – seen as a process – is embedded in time. The time concept represents a fundamental challenge in philosophy because our thoughts about the social world and time reside inside time itself. It may be debated whether there is anything that exists outside time. As foresight mostly deals with the temporal called 'future', it is vital to establish a kind of consensus within which foresight management can operate. In foresight, the time concept is reconstructed. Often, we divide the time span of the future into short, medium and long-term perspectives; short being 5-10 years, medium 10-20 and long-term 20-30 years and beyond. This time perspective is clearly socially constructed, but for what purpose? A plausible explanation for the conventional use of time horizons in foresight may be found in the purpose of the foresight itself. Since most examples of foresight (like safety management) have a clear action orientation, they need a trustworthy perspective not stretching into the eternity, rather limit it to a few decades.

Implicitly, most examples of foresight apply an operational definition of time, not strictly linear, but still a chronological concept, Karlsen et al. (2010) claim:

"The past is seen as something that has ended, having no starting point but bordering the present, which in turn is defined as the state we experience now and actually live in. Now is consequently something which is there all the time, pushing the future to a state which is not actually here, other than in our minds."

The future is constantly approaching us but is reconstructed in the organisationally recognisable time horizons applied in foresight management. The reconstruction does not change the ontological characteristics of future, just make it easier for us to handle time as an embedded aspect of the changes we imagine when undertaking the practice of foresight management. Nordlund (2012) surveyed how well-known futurists considered timescales in their central works. Like Karlsen et al. (2010) on foresight, Nordlund concludes that 'the time-scale has not been given special attention', other than when specifying scale terms, like short, medium, and long (ibid, p. 413) in futures research and forecasting. Thus, these fields (i.e. foresight and safety management) do not have a theory of time, just the mentioning of time as a rather loose and boundary condition.

1.3.2 Brief outline of foresight traditions

The foresight approach is part of a wider scientific tradition: to use analyses about the past, about the present situation (diagnosis), to identify future objects and the possibility to reach them (prognosis), and how to reach the future goals (prescription). However, here again, the actual studies differ in many ways between the two extremes: on one side pure basic scientific research about the future, and on the other side pure business studies, e.g. in the context of strategic foresight management.

Georghiou (2001) has defined foresight as an approach that overlaps three other disciplines: future studies, strategic planning and policy analysis. Although 'foresight' has been connected to, or partly integrated in, other research fields, the foresight tradition as a whole has some unique elements.

Some characteristics of the foresight approach are:

- **Process:** cross-disciplinary and cross-sectoral participation, and action-oriented.
- **Time:** medium to long term perspectives (often 5 – 50 years) in contrast to 0 – 5 years for risk assessment (short perspective).
- **Goal:** aimed at present-day decisions and mobility/joint actions by identifying possible future developments, driving forces, emerging technologies, barriers, threats, and opportunities.
- **Results:** outlooks, proposals of future developments, scenarios, visions, roadmaps, and actions.
- **Prerequisite:** the world is multi-dimensional and basically uncertain and complex.

The importance of foresight studies and explanations can be illustrated by the multitude of actors who are using foresight theories and methods. Both individuals (researchers, authors, scientists etc.), university institutes and organisations (Foresight professional networks, public-sector foresight organisations, and non-governmental foresight organisations) have allocated resources in order to develop and implement foresight studies and results in many sectors.

As examples may be mentioned as networks World Future Society and World Futures Studies Federation, as organisations in the public sector National Intelligence Council and NASA /both US), The Institute for Prospective Technological Studies (EU), Government Office for Science (UK) and Norwegian Research Council (Norway), as NGOs Rand Corporation, Hudson Institute, Copenhagen Institute for Future Studies, Strategic Foresight Group and Project 2049 Institute. The reports and findings may be published in journals like Futures, Journal of Future Studies, Technological Forecasting and Change, and the Futurist magazine.

1.3.3 A promising future for a new discipline

Foresight has developed as a scientific research field during the last years and has theories, hypothesis and concepts that have been elaborated. Many universities around the world now have foresight research on their research agenda, and some have also established scientific degrees and education programmes. Outside of universities, the foresight approach has been used by several public and private institutions, enterprises (especially multinational companies) and consultancy firms, think tanks, etc. The main implementation is connected to change management, strategic analysis, and policy development.

The EC was an early adopter of foresight research (technological foresight, regional foresight etc.). The EU Commission supported in 2009 the development of a European platform in foresight (EFP - Project no.244895). The emphasis by the EU institutions stimulated and created innovation across the EEA, as national initiatives, and new research programmes. The goal was not only to develop a broad spectrum of methods nor to introduce a new kind of thinking or create valuable processes, but to direct the processes into action, which could enhance constructive changes in today’s practices.

Some numbers can illustrate the focus the EU has had on foresight. A search of publications via the EU Science Hub produces 452 hits on foresight. Among them, four books and 180 articles. In addition, EU has organised several conferences, workshops, scientific programmes, and expert groups in the foresight field. The scope has been very wide, ranging from global perspective, as ‘Vision of the world in 2035’ – a foresight report issued by The Defence Technical Information Center (US) in 2016, via many environmental topics, such as climate change, land use, water usage, wind potentials, weather-related hazards and regional climate, to government, migration, employment, and big data in road transport policy, as well as nanotechnology, low carbon energy technologies, and sustainable food and nutrition security – all key words from reports published in 2018/19. Concerning today’s organisation, EU has established a separate Unit for the Foresight, Behavioural Insights and Design for Policy at the Directorate General Joint Research Centre (JRC) in Brussels.

In the EU, however, programmes like Horizon 2050 are formulated in terms of values and goals and not in terms of quantified performance indicators with various options for adaptation and transition strategies. They do not indicate how to achieve and how to assess these goals and values. This is left to underlying scientific research and development programmes. Such programmes, however, frequently restrict themselves to the early phases of innovation and transition processes, as expressed in the notion of Technology Readiness Levels (covering TRL 1-3 on a scale of 1-10 discriminating 10 phases in the S-curve of system life cycles). Later phases of this TRL process are left to applied sciences (4-6), industry (7-8) and private entrepreneurs (9-10) which take the final steps to their market. In those latter stages, the information on the developments foreseen has become private company confidential assets. By definition, foresight in early phases of development should enable democratic participation on the foreseeable consequences in the mid- and long term for society in general, based on knowledge and insights that are open to scrutiny from different perspectives, values and interests.

Defined in this perspective, foresight is:

- a process, discriminating several steps;
- a focus on predefined aspects, symptoms, and patterns; and,
- a judgement call, identifying values and decisions from a multi-actor perspective.

In general, foresight assessment can be built up by combining tools and techniques from different domains and disciplines, stakeholder perspectives and value judgements.

In foreseeing the acceptability of future performance, innovations and transitions suffer from a phase called 'Valley of Death'. After an initial start, setbacks occur that may oscillate into unforeseen stagnation and failure. Many promising socio-technological developments do not survive these setbacks and perish. Because such problems may emerge later than foreseeable on the short term, a (specific) time horizon should be identified in which foresight is a reliable, plausible, credible and feasible predictor for future performance.

Potential building blocks for such a foresight process are:

- iterative assessment of findings and change agents by the Cyclic Innovation Model (Berkhout, 2000);
- presumptive anomaly as expressed in the Variation Selection Model (Vincenti 1990);
- identification of showstoppers/stealers and disruptive factors in the innovation process;
- identification of societal changes, values, business models and risk awareness, perception and appreciation;
- decomposition of a systems architecture and dynamics with its safety critical decisions during design, development, introduction, midlife upgrade and demolition;
- identification of knowledge deficiencies, assumptions, simplifications and limitations of the scientific body of knowledge, available during several phases of assessment;
- feedback from reality across domains, disciplines from multiple perspectives;
- similarities with socio-technological projects in the past as a learning experience.

In addition to the dynamic role the European Commission and its departments have had in developing foresight as research and a tool for decision making (including the shortcomings), a growing national interest in the foresight discipline has, during few decades, fostered several research institutes, research programmes, books and reports, conferences, workshops, and education at university level throughout Europe (see also 1.3 above).

1.4 Safety: investigations and the 'modern' systems approach

In the Anglo-Saxon safety debate, a predominant and relatively pessimistic retrospection prevails. Systems are believed to be too complex for foresight and risk assessment to deal with. Taleb (2008) launched the metaphor of 'Black Swans' as the ultimate inability to explore and comprehend socio-technical systems. And, as Donald Rumsfeld (US Secretary of Defense, 1975-1977 and 2001-2006) suggested, 'unknown unknowns' may always limit our knowledge of the future. Safety science seems to be at the edge of a paradigm shift, both from a theoretical and a practical perspective. The European safety science community study a wide array of new approaches. Some challenge the validity of safety science as a science (Safety Science, 2014), while others proclaim new safety concepts and notions, such as Resilience Engineering, a 'New View on Human Error' or Safety I and Safety II. Such developments challenge and redefine commonly shared notions such as precaution, cause-consequence relations, human performance, cognition, and culture with sometimes far reaching consequences for their application. ESReDA advocates the generic value and applicability of safety investigations across industrial domains and scientific disciplines. ESReDA foresees a predictive foresight on safety and its integration in a system engineering perspective. In several industrial sectors with a high-tech nature, safety is considered a shared responsibility, superseding a single actor or mono-disciplinary perspective. Life Cycle Analysis seems indispensable for an assessing safety throughout the life cycle of complex legacy systems, addressing specific characteristics of transport, process, and nuclear power applications.

Within safety, it may be useful to measure 'weak signals' and other indicators. There are various approaches that help: investigation, scenarios, risk analysis and assessment.

Future thinking may be in use in different industrial sectors (such as energy production, the production of chemical substances and products, consumable production, transportation and to some extent also in the consumer-/service sector), but often restricted to a short or medium-term time horizon.

1.4.1 Safety in legacy and modern systems

Such new thinking was accompanied by a change in moral and ethical values on safety. Traditionally, technical design has relied on notions such as failsafe and safe rational decision-making theories do not provide satisfactory explanations of abnormal life, crash worthiness, damage tolerance, compartmentation, redundancy, and reliability. But recent developments show that this is changing. With the introduction of ICT as a fundamental new technology, new ethical notions such as Value Sensitive design and Responsible Innovation principles have been developed. They deal with complexity, system design and integration of safety assessment by Encompassing Design and Multidisciplinary Design Optimisation methods, Knowledge Based Engineering and Value Engineering. New legal definitions dealing with safety assessment and liability have been introduced such as Corporate Manslaughter and Corporate Homicide; shifting social responsibilities for unanticipated consequences back to manufacturers and designers.

The consequences of application of new materials such as composites, technological innovations in ICT, food, system-of-systems networks, and Internet of Things cannot be predicted and assessed by today's evaluation methods. A new combination of learning from feedback and feed-forward is not yet developed and validated. New thinking, as illustrated by the ESReDA Cube (see chapter 7), has indicated several opportunities to tackle such quests.

Since safety of innovative complex and dynamic systems cannot be assessed based on their past performance, new approaches and notions should be developed. A distinction between socio-organisational and socio-technical system categories becomes inevitable, dealing with their intrinsic, inherent, and emergent properties as specific classes of hazard, threats, and consequences. A distinction between high energy density systems and dynamic network concepts is necessary to deal with massive instantaneous outbursts of energy of a mechanical, chemical, or nuclear nature and the way consequences propagate through networks. A new distinction should be made between normal, undisrupted performance which is highly predictable and controllable, and non-normal situations, emerging from drift, natural growth, aging and exceedance of designed performance envelopes. New mental representations of human performance become necessary, since Tayloristic models of compliant behaviour and behaviour in normal situations or normal behaviour in abnormal situations. A Good Operatorship notion dealing with competence rather than compliance is under development in several high-tech sectors such as in aviation and the maritime counterbalancing prospects of full automation towards unmanned operated transport systems (Mohrmann et al., 2015).

In assessing their safety performance, we can not only deal with new systems and technological innovation. Existing systems in their full maturity have long histories of past performance and have gone through a series of decisions, assumptions and modifications that are hardly fully known, let alone documented. The notion of transition management in matured, complex systems with a high level of technological change potential is in its early phases of development. A distinction between disruptive and derivative technology is crucial to understand its dynamic behaviour. Due to the very high-performance levels, such catastrophic consequences can manifest themselves as very high consequence and very low probability events beyond the responsibility of individual actors and entities. Interferences may occur due to unknown interrelations between components that have been forgotten, neglected or unexplored. In practice, such dynamics are consigned to the category of 'unknown unknowns' but are actually discernible as design-induced consequences during operations. Foresight also includes knowledge and operational experience-based hindsight.

The role of accident and incident investigations can gain a new dimension if such aspects are incorporated in the investigation methodology. A common investigation methodology across industries and disciplines should lay the basis for such a new approach in order to create a level playing field. This would need legal recognition and procedural embedding into practice, such as achieved in aviation by the International Civil Aviation Organisation (ICAO) in its Annex 13.

1.4.2 Foresight in technological innovation: trends and opportunities

Traditionally, many industrial companies have concentrated on learning from past events and developed internal safety policies and industry norms after that. Past events include accidents, production problems, distribution, and usage problems. Many safety authorities, including regulatory agencies, have also followed this pattern. Feedback to the design of technology and organisations and managing safety during operations have greatly benefited from such learning. Social scientists designed, created, and proclaimed a category of Non-Plus-Ultra-Safe systems, such as aviation. There are, however, necessities and opportunities to combine feedback and feed-forward learning, integrating safety as a social value at all systems levels and lifecycle phases, equivalent to health, environment, wealth, sustainability, and prosperity.

Safety management based on a systematic combination of learning of past events and issues and analysis and methods for insight into the future challenges seems still not very widespread within several key high-risk areas. This ESReDA project group aims at reinforcing feedback and feed-forward loops between hindsight and foresight experiences and expertise.

Safety is to be revalued as a strategic societal value, instead of the presently preferred notion as a key performance indicator within organisations, to be assessed against other operational aspects such as economy and efficiency. Safety is a public value, not only a corporate value within an ETTO (Efficiency Thoroughness Trade Off) decision making context on an operator level. A shift back from control to comprehension is inevitable in dealing with modern, complex, and dynamic socio-technical and socio-organisational systems in their operating environment.

Only by re-addressing the context of such systems, can a credible foresight on their nature and safety performance be established.

A transition is taking place in safety thinking. It is moving from reactive, to proactive, and to predictive thinking. This transition is reflected in thinking about both technological change and developments in society:

- in technological developments with respect to technological innovation and disruptive applications;
- in socio-economic and social developments with respect to risk awareness, perception, risk acceptance and management.

A 'Zero Vision' paradigm is emerging: no risk is acceptable and lethal accidents are intolerable. At the same time, systems become more embedded, complex, and dynamic. In the transport sector, although systems safety performance has achieved a Non-Plus Ultra-Safe (NPUS) level, the scale of operations themselves is increasing with respect to volumes, numbers and sizes of transport technologies and the energies that can be released from them. The law of diminishing returns applies to conventional safety management solutions, and new directions are needed to achieve improvements. The present authors see a trend towards new notions that deal with foresight during operations such as early warning signs (EWS), or recovery from non-normal situations achieved through resilience engineering. Both developments erode the need to remain vigilant and proficient with respect to safety. Investments in road safety have been reduced in some European countries. Consequently, the death toll in Europe is increasing again. Safety in aviation is jeopardised by the limits to growth due to the capacity of the infrastructure, both airside and landside. Such system related developments can be foreseen by analysing their architecture and exploring higher order drivers for change and efficiency, such as business models, policy making and governance.

With respect to socio-technical systems with a non-plus ultra-safe performance level (especially those in aviation, railways, maritime, nuclear and the process industry) can be considered as belonging to a specific category of high energy density systems, capable of creating catastrophic consequences of a physical nature. Preventing accidents of an unprecedented magnitude remains a prime reason for existence for safety investigations.

There is no golden bullet that will serves as the single encompassing safety performance indicator. An analysis of the safety performance in aviation indicates a complex interaction between airworthiness requirements and passenger service performance indicators. Rather than aiming at a further decrease of the overall accident rate as performance indicators, safety enhancement efforts could be invested in a better understanding of the system principles and properties. Safety investigations are a pivotal approach to this purpose.

The need for a system change can be recognised in two ways:

- an incremental shift in the derivative solutions for known problems; or
- a substantial shift marked by disruptive solutions for new problems.

In the second case however, innovation processes and adaptations cannot be implemented by a single actor or from a single perspective or discipline. The concept of cyclic innovation (Berkhout, 2000). Unlike a traditional, linear design model, cyclic innovation emphasises the complex interaction of multiple actors and paradigms. This concept promises sustainable effects, which if not predictable are at least are descriptive or comprehensible.

The magnitude of energies that are to be controlled during normal operations and can be released during accidents is comparable between aviation, railway, and the nuclear sector. However, the variations within each mode of transport are great. To demonstrate the nature of classes of socio-technical systems, a specific class of high energy density dense systems with specific catastrophic potential is defined. High speed trains, large commercial aircraft and nuclear power plants indicates Many managers do not want to invest in innovations and push their current approaches to the limits with sometimes disastrous results. (see Minsky)

Such a class of systems requires specific approaches with respect to technological foresight. A sudden release of the energy content requires specific control over recovery and rescue capabilities. Resilience alone is not enough to take control after the release of such amounts of energy. The role of the operator as the ultimate manager of the total energy content is critical as the last line of defence in controlling the stability of such systems in both normal and non-normal situations. If such systems are not inherent stable, a delicate balance must be maintained in controlling the stability and flexibility during operations. Destabilising such systems by design - such as with the Boeing737MAX, or non-normal operating conditions - such as with repair and maintenance of NPPs, or de-qualification of operator skills - such as with deprived basic flying skills of pilots, puts high pressure on operating performance standards. Foresight of potential failure modes during design evaluation, and operational feedback by weak signals - such as whistle blowers, become indicators for timely adaptation, modification, and Good Operatorship requirements.

Weak signals are not weak by definition. Based on signal theory, there are several reasons for a weakness of signals:

- strong signals can be suppressed to weak signals;
- the signal can be misinterpreted because of distortion during transmission;
- a signal can be missed in the spectrum at the receiving end;
- a signal can be overruled by a signal of another nature;
- the frequency of transmission can fall beneath a perception threshold level.

In practice, weak signal debates deal with either the technical, behavioural or social nature of signals, with primary production processes or secondary processes, while the diversity across actors and stakeholders may create confusion and disagreement of their validity as service providers for user's safety or for technical reliability.

Table 1: High energy dense systems (1 MW = 1000 kW)

	Weight **tons**	**Speed** **Km/h**	**Altitude** **meters**	**Energy** **Mega Watt**
High Speed Train	430 tons	250 km/h	ground level	1053 MW
		320 km/h	ground level	1740 MW
A380 Jumbo jet	MTOW 575	900 km/h	10,000 m	75,000 MW
	at take-off MTOW575 tons	260 km/h	ground level	1500 MW
	at landing MLW 386 tons	260 km/h	200m above ground level	1252 MW
Nuclear power plant	Average size			800 MW
	Borsele (Neth)		Sea level	450 MW
	Chernobyl		Sea level	600 MW
	Fukushima		Sea level	784 MW

1.5 Foresight in a World at Risk

Many countries have developed contingency plans for tackling worst cases and wicked problems. These are most often based on foresight methods and, notably those that use scenarios (van der Heijden, 2005) in which the most dramatic outcomes are described. Scenarios usually relate to outcomes that can be described as probable, plausible, or possible (Voros, 2003). One often finds knowledge summaries of experiences that are assumed to have similar outcomes. Scenarios are conceivable e; not "wild cards".

In scenarios, it is assumed that the development of events is seldom unambiguous or predetermined. When conditions are complex, uncertain, and ambiguous—or when one needs to take a long-time perspective—it is difficult and often risky to make precise predictions. Renn (2008) proposes a classification for risk management where methods and procedures are linked to the concepts of complexity, uncertainty, and ambiguity. The 'Achilles' heel' of such risk and crisis management models lies in the 'translation' from challenges, goals and tools to action and active preparedness.

The Covid-19 pandemic can be used as an illustration of the treacherous nature of foresight management, i.e. foresight as a management capability (Amsteus, 2008); words and plans are not translated into resilient action. Thus, the scenarios preparing for pandemics like this become just stories of a foretold illness and death for most countries.

1.5.1 The Coronavirus pandemic

On March 11th, 2020, the World Health Organisation officially changed its designation of SARS-CoV-2, the illness caused by a new coronavirus, from an epidemic to a pandemic. Earlier, on 31 December 2019, China informed WHO about several cases of a new pneumonia, possibly originating from a fish market in Wuhan, China. On 7 January 2020, the virus emerged in Europe. Within few weeks, it spread globally to become a pandemic that affects an exceptionally high proportion of the population. Covid-19 is the unofficial name of the disease caused by the SARS-CoV-2 virus.

What do we (the authors as lay people) know about the coronavirus? At the outbreak, not much. We know that coronaviruses are rather common human and animal viruses. Four such viruses cause symptoms of the common cold, and three (SARS-CoV, MERS-Cov and Covid-19) cause more serious lung infections (pneumonia). Like SARS and MERS, the novel Covid-19 is a disease that starts in animals and is initially transmitted from animals to people. We also know that the virus is not a living organism, but a protein molecule. It is covered by a protective layer of fat, which, when absorbed by the cells of the eyes, nose and the inner lining of the cheeks, changes its genetic code (mutates) and converts them into aggressor and multiplier cells. Since the virus is not a living organism, it does not die as such but disintegrates over time. The disintegration time depends on the temperature, humidity and type of material where the virus particle lies.

Besides these facts, we have learned that the virus is highly contagious and when resulting in the Covid-19 disease, may cause severe acute respiratory syndrome, and even death, particularly in elderly people. However, the virus is fragile, only protected by the thin outer layer of fat. That is why we have learned that washing our hands with soap is the best remedy to protect ourselves. The foam dissolves the fat layer, the protein molecule disperses and breaks down on its own. However, the recommendations from the authorities to wash our hands with soap for 30-60 seconds, practice social distancing, avoid travels by public transportation, self-isolate when needed, etc., is far easier to say than to practice. To convert the habits of the population in such manner is not easy, and the success is rather patchy in the global arena.

1.5.2 Any early warnings?

The Covid-19 is novel and not identified previously, and it is different from those that cause cold or even SARS and MERS. At least in Europe and the US, seemingly most public recommendations and measures were reactive and imposed late in the transmission cycle when proactive trend spotting, compulsory and collective preventive actions, and a genuine global emergency preparedness were needed.

To identify and analyse weak signals and early warnings is an important brand of foresight studies. The core challenge is to recognise phenomena that have crisis potential and to assess appurtenant risks and emergency options early enough to handle these strategically (Karlsen & Øverland, p. 145-146; Rossel, 2011; Kaivo-oja, 2012). So, could this corona virus pandemic and the global breakdown resulting from it have been foreseen, given the experience with previous pandemics; e.g. the Spanish Flu in 1918-20, the Asian flu in 1957, the Hong Kong flu in 1968, SARS in 2002, the Swine flu in 2009, the Ebola epidemic in 2014 and the MERS coronavirus epidemic in 2015? Arguably, should all nations have been on alert to make-sense of the initial indications sent from China?

Apparently, many medical and scientific authorities and groups projected very negative scenarios for the pandemic globally and nationally and these projections were intended as warnings. In 2019, the US Department of Health and Human Services carried out a pandemic exercise named 'Crimson Contagion'. This imagined a flu pandemic starting in China and spreading around the world. The simulation predicted that 586,000 people would die in the US alone. The core scenario message was, according to a group of New York Times journalists, rather scary (Sanger et al. 2020):

WASHINGTON — The outbreak of the respiratory virus began in China and was quickly spread around the world by air travellers, who ran high fevers. In the United States, it was first detected in Chicago, and 47 days later, the World Health Organization declared a pandemic. By then it was too late: 110 million Americans were expected to become ill, leading to 7.7 million hospitalized and 586,000 dead.

However, did this scenario trigger an alert to the US authorities? Hardly. Such projections may have generated increased anxiety, but arguably, that is much better than complacency. The journalists claimed it only resulted in a (not to be disclosed) report, emphasising, 'how under-funded, under-prepared and uncoordinated the federal government would be for a life-or-death battle with a virus for which no treatment existed'. Moreover, the US president for weeks stubbornly preached that the pandemic was negligible and controllable. By 3 April 2020, the Johns Hopkins University (JHU) reported that the number of people confirmed infected by the virus exceeded 1 million (thereof 250,000 in the US) and the death toll over 500,000 globally. Five months later Worldometer reported 27 million infected and nearly 900,000 deaths .

MacKay and McKiernan (2004 point out the role that hindsight plays in foresight studies. They argue that the past is not an isolated static state, but one that is clearly linked with the future. However, biases may influence our perceptions and conceptions of the past. These biases act as constraints on our ability to understand the driving forces that emerge from the past, play-out through the present and become the critical uncertainties in the future. A foresight bias results from a shallow perception of history and is characterised by a combination of hindsight biases, creeping determinism, and searching for information that corresponds to people's views about both the past and the future. The authors propose counterfactual analysis as an antidote to the foresight bias, linking counterfactuals with scenarios, thus translating the experiences of the past to future challenges. Unfortunately, such techniques seem to have been largely neglected in recent scenario studies like the one performed by the US government.

On the other hand, are better, more useful ideas to be found in the literature on 'risk society', on decision-making in situations of (extreme) uncertainty, or on anticipation, resilience, and sense-making?

1.5.3 From micro-cosmos to macro-chaos

Seemingly, most governments have not had in place an early warning system and supporting decision mechanisms that could have prevented the outbreak or at least lessened the spread of the virus to a tolerable extent and at a more controllable speed. A capacity for early warning could have made it possible to mount a proportionate response at the initial breeding ground in China, and to instantly disseminate the information to the rest of the world. In January 2020, Chinese researchers had published the genetic code of the virus, a requirement necessary to develop test equipment and start developing a vaccine. Some countries like China, South Korea, Singapore and Germany effected comprehensive testing and other measures and managed to restrict the spread and the number of deaths. Iceland is the only country that did a massive testing of citizens having no symptoms, which may be a key to understand the real spread of the disease.

However, many countries hesitated to act until the disease exploded in Europe and the US in March 2020. This forced governments to adapt their policies ad hoc and to express strong opinions in areas they knew little about. Thus, we witnessed quite different measures and opinions in various countries, varying from initial neglect and laissez-faire to extensive shutdowns of society. In some countries, e.g. Sweden, UK and the US, leaders proclaimed that millions had to be infected and many thousands of elderly people had to die before the pandemic would burn out. Others, e.g. Denmark and Norway, declared the opposite view: vulnerable groups (e.g. elderly, disadvantaged, physically impaired people, people living in highly exposed housing, etc.) should receive extra attention. Therefore, the Danish and Norwegian governments closed schools, bars and restaurants, shops, dentists, hairdressers, exercise studios, physiotherapists, etc. Every public place where people usually met and mingled posed a threat to these groups and the favourite measure was to lock them down.

The domino effects of the corona crises are widespread and total. In many countries the health care system is loaded to maximum capacity. Some countries like Italy, Spain and the US, most probably face a collapse or must shift to seemingly harsh triage decisions unknown in peacetime. The number of businesses that instantly locked down and the number of unemployed skyrocketed after the pandemic was declared. The economic pain has spread at a velocity equal to the spread of the virus itself. In many countries, the economy falters, as business owners and employees wonder if any stimulus package will reach them. The longer the economic meltdown lasts, the more unlikely it becomes that the community will recover its former vitality and, moreover, the greater the risk of unsettling the social fabric that holds the economy together. Predictions made in popular and social media is that the pandemic will change the world forever (Allen et al. 2020).

1.5.4 Revisiting the Risk Society in a world without a leader

In 1986, Ulrich Beck published the now classic Risk Society. The book called attention to the dangers of environmental and industrial catastrophes and changed the way in which we think about contemporary societies. Ever since, the global dangers highlighted by Beck have taken on new forms and assumed greater importance. Financial crises have produced worldwide consequences that were completely out of control, terrorism has shifted from the regional to the global arena, waves of pandemics have swept the planet, and climate has been the most significant change-maker and defining marker in politics.

The term risk society describes contemporary social communities that seek to organise themselves in response to a future marked by global disasters, e.g.: technological vulnerability, climate change, pandemics, terror, military conflicts, political, economic, and social unrest. Global structures decouple many of the risk factors from defined localities and territories. The impact of today's and future risks can be universal. They will cross boundaries between states, geographical regions, gender, class, and cultures. Communities that pay close attention to a future under uncertain, ambiguous, and complex conditions will launch measures to prevent and reduce the impact of both current and future risk factors. In this way, they will be reflexive, expanding the capacity to sense and make-sense of novel emergence (e.g. a crisis), as well as setting the stage to reconsider the conception of a safe and robust society. However, there is a huge gap between the present reality and the ideal future solution.

Arguably, modern society is lacking the proper capability to understand the role of the future, given our perception of the past and present. This hampers the capacity to intercept emerging global shocks and anticipate novel trends, as well as setting the stage to reconsider our conceptions of present human agency. While amid the coronavirus pandemic in 2020, the point made by Beck (1999, p. 78) reminds us on the unfeasibility of being informed and rational in managing 'unknown unknowns':

"The ultimate deadlock of risk society … resides in the gap between knowledge and decision: there is no one who really knows the global outcome – at the level of positive knowledge, the situation is radically 'undividable' – but we nonetheless have to decide … so risk society is provoking an obscene gamble, a kind of ironic reversal of predestination: I am accountable for decisions which I was forced to make without proper knowledge of the situation".

The global nature of this pandemic, and the unknown features of the disease Covid-19, is changing world politics, in which risks are handled individually by various nation states for political gain. It demonstrates a global inequality and a local vulnerability and states a position far from what Beck (2009) calls a 'cosmopolitan material politics'. Rather, it is what the historian Yuval Harare characterises as (2020, p. 42-43), a 'Disease in a world without a leader'. The acute crisis facing humanity is not only due to the corona virus, but also because of a lack of trust and solidarity between humans:

"To defeat an epidemic, people need to trust scientific experts, citizens need to trust public authorities, and countries need to trust one another".

The effects of the coronavirus pandemic are evident everywhere: empty streets, shuttered shops, overflowing hospitals; closed kindergartens, schools and universities. Millions of people are laid idle by a State-ordered work ban, by the shared lack of business dealings, or by being forced to work from their bedrooms. However, despite the similar global effects, the world lacks a leadership with a common and unified strategy to cope with the coronavirus pandemic.

1.5.5 Future global chocks and the need for resilience

With no vaccine yet available, the pandemic is a drag on the global economy and a blight on social life. Arguably, there is a lack of societal resilience, meaning a capability to tackle and recover from such global shocks. However, there is abundant literature and studies reminding us about the most important lessons from past crises. One such is the OECD study on 'Future Global Chocks: Pandemics' which states (Rubin, 2011, p. 80):

"The key to any progress against infectious diseases is a structure that brings together these diverse interests in a lasting fashion. Without such a structure, the commitment to reducing the impact of infectious diseases on our national, economic and personal security will be subject to the political vagaries of the moment, leaving us unprepared for the next global health crisis."

The OECD study argues of international research centres on for the setting-up infectious disease, to serve as a nucleus for safe applications of interdisciplinary sciences globally to the benefit of all.

Another strand comes from the academic world, examining the questions 'what do we talk about when we talk about managing crises', and 'what are the threats, dilemmas and opportunities'? A point of departure may be the book 'Coping with Crises' (Rosenthal et al., 1989). This addresses major crises during the 1970s and 1980s and was followed-up ten years later by 'Managing Crises' (Rosenthal, Boin, and Comfort; 2001). The latter stated that, on its own, learning from the past has limited value to improve preparedness or the management of future crises.

Rather than accept this fatalist position, futures and foresight researchers point instead to the benefits of 'futures literacy' (Miller 2015, 2018). This is the capacity make sense of contemporary trends shaping the future and involves informed hindsight of past events.

In the case of the coronavirus pandemic, the role of social media disrupts the supply of objective and valid information. Fake news, speculations and unsubstantiated opinions interfere with the control that governments seek to achieve through their information channels. In opinion panels, experts are selected based on their political usefulness, or play a role as whistleblower—there to criticise official theories on what the pandemic is about, its challenges and the responses thereto. These contemporary behaviours in the media add considerably to the chaos phase in disaster management.

Informed hindsight must be related to making sense of the trends shaping the future. In his chapter on viral epidemics, Alkan (2001; p.267-280) points out that communities exist in a fragile equilibrium with their ecological environment. A disturbance of this balance can cause epidemics. Alkan argues that preventing future outbreaks of deadly epidemics is nearly impossible. What society can do, however, is organise for a resilient response that best copes with cruel decisions under conditions of uncertainty. Alkan states (2001; p.277):

'Crisis management during epidemics is not simply a function of adequate models and smart scientists. In the end, crisis managers have to make decisions that encompass more than just scientific information. They have to deal with typical crisis dilemmas. Making decisions based upon an incomplete data base is the hallmark of response to crisis. As viral epidemics emerge and re-emerge, it is preparedness, a high degree of suspicion, and rapid appropriate response that will limit the spread of these diseases in the future.'

Viral pandemics are here to stay, and they are examples of unforeseen, complex, transboundary crises with a series of domino effects on social organisation, health, and welfare. Alkan (2001, p.278) argues that while modern society is becoming more risk averse, viruses continue to modernise themselves.

If we diagnose the nature and architecture of complex systems, our ability to cope with with pandemics will no longer be restricted to responding to the consequences of disaster. The coronavirus pandemic serves as an example of a wider pattern in which viruses and diseases transfer from animals to humans. Wildlife markets, bush meat and other indigenous food chains are a primary source of contamination and spreading of new diseases. Changing the food chain and, indeed the wider system of food and nutrition is at the root of preventing pandemic events like Covid-19. Progress in the agricultural industries and virus resistant food chains will stop pandemics at their origin by coping with virus mutation, transmission to humans and across population groups, and uncontrolled spread to other world regions. Design principles regarding distributed production, unravelling chains and disconnecting networks to prevent knock-on effects, are already very well established in other industrial sectors. We can learn a lot across industry at the level of functional relations and design concepts. Analysing and understanding dynamic system behaviour and the architecture of complex systems are a prime challenge to robust systems design (Klir, 1987).

1.5.6 Chance favours the prepared mind

A transnational response structure is urgently needed. In his inaugural address as a newly appointed professor and dean at the opening of the Faculté des Sciences at Lille (7 December 1854), Louis Pasteur claimed that," In the field of observation, chance favours only the prepared mind". Strategic planning of emergency preparedness and management calls for building societal resilience capacity to sense and respond to emerging, and often what Beck (1986) named, 'invisible' risks. The coronavirus is an example of such hidden enemies. People may be infected and contagious without knowing, since many of the symptoms are mild and resemble more common diseases like colds and flu. Partly, Covid-19 is covert, invisible and not identified in large parts of the population, but partly evident, contagious and deadly in other population segments.

It is urgent to ensure that critical systems are robust, diversified and hold adequate reserve capacity. That has apparently not been the case for most countries prior to the outbreak of the coronavirus pandemic in 2020. The early warning systems were not in place, and even the reactive capacities are seemingly inadequate. Furthermore, the global partnerships are too weak and not coordinated to receive, share and integrate sources of information conducive to handle the pandemic and the societal risks resulting from it.

We know from research on previous crises that it is more important to understand the phenomenon than just to mitigate the consequences. Although we do not know all aspects of the coronavirus and the pandemic it has caused, complexity can be beaten by transparency, not by simplicity. The focus has been on the emergent consequences of exposure rather than on the transmission mechanisms themselves. It is the size of the consequences, rather than the nature of the pandemic, that has driven governmental responses. This is not an act of resilience and anticipation, preparing to prevent a next pandemic; just a firefighting effort to save what might be left after the current crisis. Consequently, it pays to be prepared.

1.6 Foresight towards a full information paradigm

Cacciabue (2004) discriminates two types of risk analysis: retrospective and prospective studies. These are complimentary and contribute equally to the development of assessment and measures. This approach rests on both empirical and theoretical platforms for evaluating socio-technical context and models. In practice, retrospection aims to identify data and parameters associated with specific occurrences, operational experiences, and context. Prospection, in contrast, aims to evaluate consequences of scenarios using a spectrum of methods, models and techniques. Taken together, this framework identifies the knowledge base needed to foresee future developments, their boundary conditions, initiating events, systemic process, and failure modes (Cacciabue 2004). Applying this approach may provide an encompassing set of safety performance indicators for foresight of the safety states of a system and to identifying areas of concern. Such areas are based on information collection and processing as described by Klir and Godet.

1.6.1 A full information paradigm

The simultaneous use of feedback and feed-forward mechanisms can be theoretically underpinned by the 'full information paradigm' of Klir (1987)—see fig 1. According to this paradigm, the body of knowledge and experience acquired in a system over decades, provides a basis for considering safety and risk (Stoop, 1990). Such a body of knowledge dominates legacy systems such as energy, process industry and transport; it makes the Non-Plus Ultra-Safe (NPUS) safe, but also reluctant to change. Their ability to adapt is hampered by vested mental constructs, assumptions and simplifications, expertise and consensus on scientific paradigms, methods, notions and techniques, both theoretical and practical.

'Old views' have to be discarded and abolished in case of a paradigm shift in safety thinking, similar to Schumpeter's 'creative destruction' on economic theory. Otherwise an opaque blending is created by mixing old and new views into a hybrid concept. In the past, we have seen a stall of such a dialectic process by proclaiming A versus B concept of safety, to be replaced by another version of C versus D. Such a debate does not restrict itself to an academic discourse but may hamper progress by creating confusion during application of these versions in legacy systems. A fall back on old views and repetition of debates across domains and disciplines frequently occurs, allocating public, corporate and personal responsibilities for safety, emphasising the roles of whistle blowers and regulators.

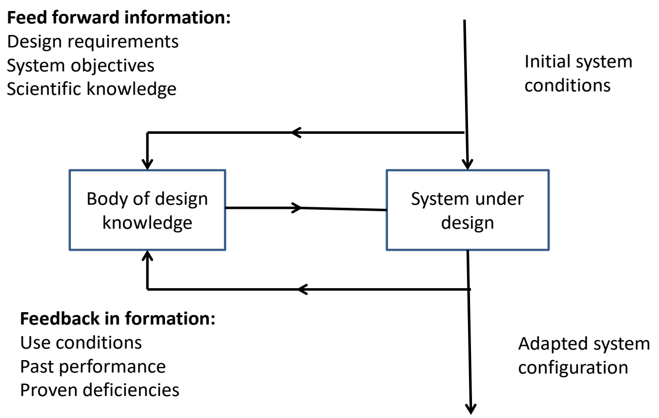

Figure 1: Full information paradigm (Hierarchical ordered control loops) according to Klir (1987)

Solving complex problems would be done better if there was greater scope for individuals to innovate solutions. To create space for individual competence, creativity, flexibility and innovation, we advocate the abolition of three obsolete notions: simplified accident models, human-error schemes, and judicial concepts of cause and blame. Taking each of these in turn:

- predefined, simplified accident models should not be used to reconstruct the course of an event. This is 'model-forcing' rather than 'model-fitting'. Instead, groups of actors should develop shared understanding of an event by using the scenario concept;
- 'human error' schemes prejudice problem-solving. Instead, a new view on human behaviour should be adopted as this invite, rather than precludes, deeper understanding of human behaviour in context;
- judicial concepts of blame and cause are fitted to the legal context of deciding liability in the courtroom. Their application should be challenged as a means for actors to understand multilinear interactions. Instead, these interactions are better understood using systems concepts, especially as the operation of feedback and feed-forward.

Abolition of the use of accident models, the notion of cause and human error as proposed by social scientists is likely to meet resistance to change due to:

- a lack of understanding of system engineering theory by non-technical scientists and practitioners;
- mono-disciplinary paradigmatic perspectives in psychology on human performance and cognition;
- disciplinary demarcation lines between technical and social sciences, and;
- cognitive stubbornness and resistance to change at both an individual, corporate and governance level.

1.6.2 The Greek Triangle according to Godet

The Greek Triangle, as formulated by Godet in 1994 and later developed into the networking action scheme (Godet 2010), sees prospective strategy as a management tool that links anticipation to action through appropriation.

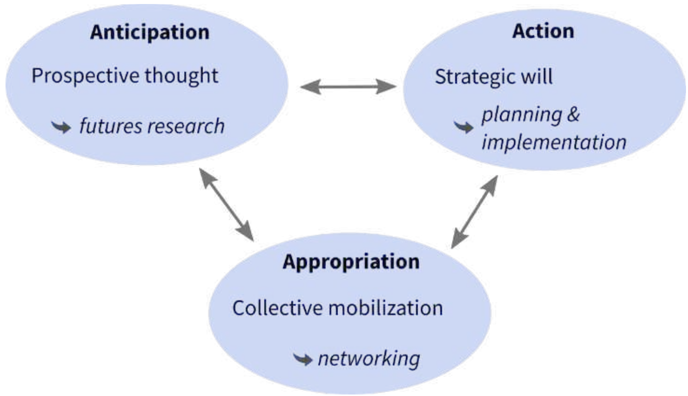

Figure 2: The relationship between Anticipation, Action and Appropriation (Source: Adapted from Godet 1994, p. 4)

Godet defines these terms:

- anticipation is the awareness of the future, and prospective thought;
- appropriation is joint commitment, collective mobilisation and sharing of values; and
- action is strategic resolve, and planning.

The triangle helps to discern the plausible future, and to develop strategy accordingly.

The three points of the triangle represent the pull, or image of the future (visual); the push, or drivers, of the present (quantitative); and the weight, or barriers, of the past (deep structure).

1.7 Foresight in safety – taking actions for a change

1.7.1 Corporate foresight

Corporate foresight is often seen as the capability of an organisation or firm to ensure its long-term survival and competitiveness by envisaging trends and detecting changes and consequences.

Corporate foresight (Rohrbeck, 2010) has been defined as: *'…an ability that includes any structural or cultural element that enables the company to detect discontinuous change early, interpret the consequences for the company, and formulate effective responses to ensure the long-term survival and success of the company.'*

However, due to shortening of product lifecycles, increased technological change, increased speed of innovation, and increased speed of the diffusion of innovations, the long-term perspective has become hard to defend. Rather, there is a constant pressure to explore and develop new business ideas, penetrate new markets and compete with aggressive competitors.

Rohrbeck et al. (2015, p. 8) argue that three novel areas of research within the field of corporate foresight should be pursued:

- Managerial cognition, which emphasises the role of the individual and group cognition in shaping perception and influencing decision-making;
- Forward-looking search, which is based on the behavioural theory of the firm. It emphasises that, as individuals are subject to bounded-rationality, firm decision-making cannot be conceptualised as purely rational or produced by analytical reasoning;
- Prospective sense-making, which considers organising as a process in which individuals build on their past experiences, and collectively reflect on these episodes to converge behind common objectives and lines of action.

Hopefully, such research endeavours would also be conducive to forming a research stream on strategic safety foresight in organisations.

1.7.2 Tools and techniques

Foresight studies must be integrated into the total safety administration of high-risk companies, industrial factories, transport enterprises, etc. This means adjustment of all the major elements of the current approach as developed over decades. These elements include risk analysis, accident investigations, mapping of unwanted events, dynamic learning, legal requirements, internal safety standards and procedures, competence development, continuous safety education, training, and change management. Hindsight lessons, insight competence and foresight studies must be part of a holistic safety management system. Debatably, the implementation of such a holistic model seems today rather rare in most private companies and public enterprises.

The foresight discipline has developed and enlarged its methodology over the years. In particular, the use of scenarios, the Delphi technique, panels, and games have become widely used, often in combination with other methods. At the same time, the content of the methods has partly changed. Whereas these methods were once the province of experts, now they are increasingly participatory; with employers, consumers, and citizens as actors.

Scientists use future techniques in their research (futurists) as do think-tanks and similar institutions. They draw on a wide range of foresight methods, including those listed in Table 2. The list is merely illustrative, and other methods exist. Note that these methods can be used for a wide variety of purposes e.g. diagnosis, prognosis, prescription or being normative, predicative, etc.

Table 2: List of foresight methods. (Popper 2008a&b; Karlsen & Øverland 2010)

• Anticipatory thinking protocols • Causal layered analysis (CLA) • Environmental scanning • Scenario method • Delphi method • Future history • Monitoring	• Back-casting (eco-history) • Cross-impact analysis • Futures workshops • Failure mode and effects analysis • Futures wheel • Technology road mapping	• Social network analysis • Systems engineering • Trend analysis • Morphological analysis • Technology forecasting • Visions

The list is not at all complete. Several authors include other methods in their foresight research. The point of this list is that foresight methods may be used for different purposes, e.g. diagnosis, prognosis, prescription or being normative, predicative, etc.

Amongst those methods listed in Table 2, trend analysis is particularly widely used by e.g. 'public planners, think tanks, foresight departments in companies and multinational enterprises. In fact, trend analysis, which is widespread within several commercial sectors, research institutes, and universities, have become a necessary tool in strategic planning, including policy making and decision making. In a systematic approach to safety, trend analysis should be linked to two important fields: the connection to knowledge, to risk and change management and to risk analysis and learning from accidents and incidents.

Three recent different examples of trend analysis with different perspectives are shown below.

Table 3: Examples of trend analysis topics from three institutions

Institution	Institution	Institution
Simon M Atkinson/IPSOS[5]	**WATCH INSTITUTE[6]**	**FORBES[7]**
1. Dynamic Population Growing Opportunity and Growing Inequality 3. Megacities 4. Increasing connectedness and decreasing privacy 5. Healthier and sicker 6. Rise of individual choice and fracturing of the mass market 7. Rise of the individual and decline of social cohesion 8. Cultural convergence and increasing extremes 9. Always on versus off the grid 10. Emergence of public opinion's revolutionary force	1. Demographic shifts 2. Economic outlook 3. Geopolitical Issues 4. Technological Advances 5. Environmental challenges Watch Institute has identified 5 megatrends in each of the sector mentioned above – and list, describe and analyse altogether 25 megatrends.	1. The increasing datafication (sic) of our lives 2. The Internet of Things and how everyday devices are becoming more 'smart' 3. Exponential growth in computing power is fuelling massive tech advances 4. The incredible rise of artificial intelligence 5. The unstoppable freight train is automation 6. 3D printing opens up amazing opportunities for manufacturers (and others) 7. We're interacting with technology in diverse ways 8. Blockchains: An invention that could change our world 9. Platforms are the way forward for businesses

1.7.3 Foresight: from safety, via anticipation towards resilience

Park et al. (2013, p. 358-359) claim that in complex systems, risk analysis alone is inadequate to fully protect system functions and components.

This is because: "The classic risk analytic paradigm begins with hazards identification – an exercise that is problematic in the context of complex systems and emergent threats because hazards may be largely unknown".

Instead, they propose to combine risk analysis with what they call resilience analysis when working out catastrophe management plans. They claim that resilience in a complex systems context is a 'dynamic, emergent property in the context of a specific failure scenario'. Both risk management and resilience are vital to every organization. While risk analysis is well known, especially in private sector enterprises, prominent in the resilience analysis are four recursive processes, which may be modelled as a cycle (Park et al. 2013, p. 360):

1. Sensing, by which new system stresses are efficiently and rapidly incorporated into current understanding;

2. Anticipation, by which newly incorporated knowledge gained by sensing is used to foresee possible crises and disasters;

3. Adaptation—the response to the information produced by sensing and anticipation;

4. Learning, by which new knowledge is created and maintained by observation of past actions.

Resilience and anticipation deal with risks in different, but compatible, ways. Anticipation is the process of becoming aware of previously unanticipated events. According to Wildavsky (1991), anticipation is a mode of control by a central mind or actor; efforts are made to predict and prevent potential dangers before damage is done. For example, accident prevention is based on anticipating potential accidents and is enhanced by three processes of mindfulness: (1) preoccupation with failure, (2) reluctance to simplify interpretations, and (3) sensitivity to operations. (Weick and Sutcliffe, 2001; p.54). It is a strategy which aims to cope

[5] *https://www.ipsos.com/sites/default/files/10-Mega-Trends-That-are-Reshaping-The-World.pdf, Accessed 06 January 2020*

[6] *https://issuu.com/megatrendswatch/docs/global-megatrends-preview?ff=true, Accessed 06 January 2020*

[7] *https://www.forbes.com/sites/bernardmarr/2017/12/04/9-technology-mega-trends-that-will-change-the-world-in-2018/#23c8f0805eed, Accessed 06 January 2020*

with known threats that an organization is aware of. Anticipation means to direct your resources at one or a few specific threats, so you are best capable of dealing with that specific scenario. The point is that anticipation as a safety strategy was insufficient in today's uncertain and complex world. Under circumstances of great uncertainty and complexity, resilience is a better strategy than anticipation for managing risks. On the other hand, resilience is the capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back. Dealing with unknown hazards 'as they declare themselves' is another expression for resilience (Wildavsky 1991). This perspective from Wildavsky has been further developed by several scholars within organization and risk management theory. One perspective is 'high reliability organisation' theory. Another perspective that builds on Wildavsky and the literature of high reliability organisations is 'Resilience engineering'. Debatably, Wildavsky`s dissection between anticipation and resilience has been blurred in this literature since the resilience concept in the Resilience engineering literature includes both what Wildavsky would have denoted anticipation and resilience.

Let us take a closer look at the resilience concept and the theoretical puzzle. As stated above, resilience is the idea that an individual, a technological or social system has the capacity to handle events that challenge boundary conditions. It encompasses the ability to prevent something dysfunctional from happening, or the ability to prevent something dysfunctional from worsening, or the ability to recover from something dysfunctional once it has happened (Westrum, 2006). Dysfunctional challenging events occur because plans and procedures have fundamental limits, or because the environment changes, or because the object itself adapts, given the changing pressures and expectations for performance (Woods 2009). The capacity to respond to such events, (i.e. dysfunctionalities) resides in the expertise, strategies, tools, and plans that people in various roles can deploy to prepare for and response to specific classes of change. Hence, we expect resilience to demonstrate an ability to avoid problems, to handle problems when they must be faced and to recover from damage once the dysfunctionality has happened.

Resilience is also the process of being mindful of errors that have already occurred and correcting them before they worsen or cause more serious harm. Resilience is related to accident mitigation and enhanced by two processes of mindfulness: (1) commitment to resilience, and (2) deference to expertise. Organizations committed to resilience develop knowledge and skills to cope with and respond to errors, capability for swift feedback and swift learning, speed and accuracy in communications, flexible role structures, quick size-ups, experiential variety, skills at re-combining existing response repertoires, and comfort with improvisation. Such organizations move decision-making rapidly to those with the necessary expertise (Weick & Sutcliffe 2001).

Besides, resilience may be seen as a 'dynamic non-event' (Weick 2001), it is both dynamic and invisible. It is dynamic because it is an ongoing condition in which problems are instantly controlled due to compensating changes in components. It is invisible in the sense that it does not reveal the worst case scenarios, i.e. how many mistakes and breakdowns could possibly happen and in the sense that reliable outcomes are constant, i.e. there is nothing to pay attention to since nothing seemingly is happening inside the intended performance envelope. Visibility should be enhanced by identifying operational scenarios other than incidents and accidents.

Hindsight is the ability to understand, after something has happened, what should have been done or what caused the event. It is another way of describing retrospection. Hindsight is a useful skill that can be cultivated. Hindsight often refers to a lesson learned from something that went wrong. In hindsight, you'd know you should've paid attention to the giant 'danger' sign. In the context of foresight studies, hindsight is a form of organisational sense-making, and resilience is seen as the capacity to bounce back to normal operations after a catastrophe or some other major mishap.

Arguably, such concepts should contribute to the ambition of linking the theoretical world of foresight and the practical world of safety closer together, by explicating key concepts and implicit assumptions in both fields. However, the concept of resilience seems almost ineffable: it resists definition and description. if resilience is meant to encompass both the capability to respond, to monitor and to anticipate and by the end of day also learn both from successes and failures, resilient engineering research should illustrate the necessity to link these aspects when building resilience in organisations. An open question is - what concrete things and conditions could an observer use to make sense of resilience in airline operations, railways, NPPs and other sectors mentioned earlier in the chapter?

Besides, the theoretical puzzle prevails: How do we recognise resilience in ontological terms as long as we do not expect a person or system having a total breakdown? Subsequently, how do we perceive the ontological and epistemological aspects of resilience to be visualised and presented? Resilience is not only a technological device, but also covering an organisational or an individual capacity meant to prevent dysfunctions to materialise or to appear if, and only if something totally unexpected happens. We may say that resilience is a systemic phenomenon that is not expected to be activated, i.e. it is not foreseen to have a future. However, if a breakdown happens, resilience is expected to serve as a safety net recovering the capacity of the system or the individual. Can this puzzle ever be solved?

1.7.4 What next?

More research beyond the level of short term, specific impact assessment studies, is needed at both national and EU levels to identify adequate and appropriate methods; and to investigate the utilitarian value of applying corporate (management) foresight perspectives to safety in a medium and long-term perspective.

1.8 Foresight in safety: the new approach

1.8.1 Five major elements in the new approach

Innovation and pioneering work is needed to apply foresight theories and methods in the field of Safety. Apart from national security, food and nutrition safety and a few other fields, safety seems to be rather absent as research object in the foresight tradition.

The new approach of the ESReDA Project Group 'Foresight in Safety', largely informed by the situation in European high-risk industries and public safety institutions. It can be characterised by five factors:

1. A broad perception of the concept safety which may benefit from the scientific foresight tradition. So far, it seems that safety in general has had a low priority in the development of the theories and the methods as well as in the practical application of foresight insights. PG's work may therefore be looked at as a kind of pioneer work trying to combine a basic area in the modern society (safety) with a very promising and innovative scientific research discipline (foresight).

2. The time horizon assumed in this study is essentially the near future (0 – 10/15 years?). This is not aligned with the traditional foresight approach which emphasises the value of a middle, or long-term, time perspective.

3. The safety setting is pragmatic. The goal of foresight work in safety should help to promote and increase safety. This study emphasises the value of hindsight experiences and learning from past events, but at the same time including proactive methods and measures: as data from early warning signs, lessons from whistle-blower-cases, the challenges with loss of memory in companies and public institutions etc.

4. We will promote a holistic programme to enhance safety in industry, transportation, public serves etc.: combining hindsight and foresight, combining lessons learned from past experiences with future trends and studies, combing systematic safety approaches from own sector and own company with experiences from other similar companies – also abroad.

5. Lastly, we will propose to explore the possibilities to meet the safety challenges (defined as total safety) within your sector with the positive effects of a synergy approach which includes a wide perspective: the potential of enhancing safety by cooperation both within and across sectors, across national borders, across scientific disciplines and traditions, combining hindsight and foresight etc.

This background is reflected in the various topics which are covered in the present work.

1.8.2 Implementing the foresight approach

Foresight as an academic, scientific discipline is, above all, characterised by three fundamental, complementary dimensions: uncertainty, complexity, and dynamic interactions.

The first dimension, uncertainty, is a consequence of choosing the future as the subject. Uncertainty increases with the choice of time frame: with near, medium and above all long-term horizons (30 – 50 years) the uncertainty factor is extremely large. In addition, a number of other choices contribute to increase the degree of uncertainty: as organisational level (group, municipality, region, nation, continent), choice of approach (such as political, social-economic, cultural etc.), choice of sector (such as business and multinational enterprises, government institutions or enterprises, ideal companies or various types of organisations, including NGOs and supranational institutions and organisations).

The second dimension, complexity, highlights the everyday phenomenon that we seldom predict the results of an innovative development. Technological innovation leads to brand new products, and new patterns of technical and social interaction. The development of products such as colour TV, personal computing, tablet devices, mobile phones, electrical and driverless cars or buses, are just a few examples from the past decades. The emergence of social media and the widespread use of digital tools such as Facebook, Instagram, Twitter, Google, Wikipedia, have gained within a few years, are others. The very complex interaction between the climate and the environment, changes in the settlement pattern (from rural to urban domination) are other examples. An important feature of the complexity of today is the tempo at which these changes occur. The pivotal function that knowledge production has gained in social developments and the enormous resources that multinational corporations can allocate to innovative operations further accelerate the tempo. The combination of complexity and accelerating tempo underline the importance of foresight methodology.

The third dimension, dynamic interactions, deals with the dimension of time. This dimension covers various time scales, both short term—during operations—and long term—throughout the system lifecycle. In foresight, time also covers transition phases and system states that emerge during the transition from one phase or state to another. In such transition periods, hybrid situations and conditions may create temporary disruptions and deviations from optimal performance which could be foreseen and addressed. Such hybrid periods may both create a better or worse performance that anticipated (Vincenti, 1990). They can be submitted to system erosion and deliberate interventions by extrapolating performance beyond design parameters (Minsky, 1986). In a foresight approach, resistance to change, system stability and system oscillation should be considered in advance as inherent/intrinsic properties to prevent emergent behaviour (Stoop, 2019).

The implementation of foresight theories and methods in the future safety work – with these three dimensions integrated – needs further research and studies, a willingness to share insight and experiences across frontiers, being between enterprises, authorities, research institutions, think-tanks, organisations – also across national borders.

1.9 Conclusions and recommendations

1.9.1 Objectives in an uncertain and complex future

'The future is complex and uncertain, and so are its threats to safety and security. These threats are in a different league to our existing approaches to safety, which operate on timescales that are too short, and with scopes that are too narrow. The fact that our approach to safety is outclassed by the threats we face [survival of mankind, climate and environmental problems, new artificial products …] seems to be either fatalistically accepted or simply not faced at all. Our contention is that these threats are tractable, but that it requires rethinking what we think we know about safety, and a readiness—urgency, even—to explore new ways. Foresight, we think, symbolises this new frontier.

1.9.2 Foresight and safety

Foresight can benefit safety. Some of the foresight methods and concepts reviewed in this chapter can be adapted to this end.

However, success is likely to be greater if the foresight community and the safety community communicate with each other.

- The foresight approach seems to have high potential utilitarian value for finding safety enhancements in the short term.
- The use of foresight notions and methods has so far only to a small degree been incorporated in systematic safety management at a governance and corporate level.
- The impact of residual risks and side-effects should be part of a foresight approach considering the long-term dynamics and uncertainty of innovative developments.
- In the foresight approach, the full information paradigm should be applied, benefiting from a feedback and feed-forward learning process
- In the foresight approach, higher order driving forces should be considered, as they represent socio-economical innovations, political philosophy, and social values.

The answer to complexity is transparency: de-risking of disruptive architecture facilitates foresight.

- The legacy of systems, their technological nature and temporal dynamics should be considered as inherent constraints. Before introducing them, the long-term effects of innovations in complex systems need to be better predicted and discussed by all affected, incl. across life cycle borders.
- More research is needed at both national and EU levels to identify adequate and appropriate methods and to investigate the utilitarian value of applying foresight in safety in a medium and long-term perspective.
- Explore the value of importing experiences and knowledge about the use of foresight methods to the safety arena.

The present authors see foresight located alongside safety insight and oversight:

- First, gain insight by safety investigations in critical events and occurrences as described in the ESReDA approach.
- Then, gain oversight by putting these events in the architecture of a systemic context, discriminating structure, culture, content and operating context
- Finally, gain foresight by understanding and predicting future behaviour of the system

Safety is an indispensable strategic value in the transition process from derivative to disruptive solutions in developing innovative as well as legacy systems. The main challenge for safety professionals is to develop new notions, methods, tools and techniques to cope with the challenges that accompany such a transition. These efforts could benefit from unexplored and so far uncharted domains and disciplines. Foresight is a promising prospect when addressing safety. But it will need global leadership. Will the UN, OECD, EU and WHO jointly support such an endeavour?

To paraphrase Richard Booth (1979) in his inaugural lecture in 1979:

“Safety is too important a matter to be left to futurologists”.

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