POLICY AND PRACTICE IN HEALTH AND SAFETY
2018, VOL. 16, NO. 2, 158–176
https://doi.org/10.1080/14773996.2018.1468005

RESEARCH ARTICLE

Preventing major accidents and the language of complexity

Ingrid Årstad[a] and Ole Andreas Engen[b]

[a]Petroleum Safety Authority Norway, Stavanger, Norway; [b]Department of Industrial Economics, Risk Management and Planning, University of Stavanger, Stavanger, Norway

ABSTRACT

In this article, the question of language is considered from the perspective of safety science, as a marker of potential limitations in current risk management practices in high-risk industries. Our main concern is understanding how the language used in daily risk management practices may serve or disserve the prevention of major accidents, as well as what opportunities being aware of such language may yield for improving current practices. We propose 10 different ways of assessing the strengths and limitations of risk management practices through the lens of the language in use. Our main intention is to clarify what characterizes the language of complexity, and how it may contribute to a more functional approach to the prevention of major accidents on a practical level.

ARTICLE HISTORY
Received 26 January 2018
Accepted 19 April 2018

KEYWORDS
Language; major accidents; accident prevention; system safety; complex systems

1. Introduction

The starting point of this article is the recommendation of Dekker (2012) to 'encourage a language, or a perspective on accidents, that is more open to the complexity, the dynamics, erosion and adaptation that marks socio-technical systems, than our thinking about accidents has been so far'. While there is much literature covering various issues concerning accidents and language, we note there is limited literature that addresses how language can influence safety management practices. We therefore want to explore why this recommendation may be necessary and how it could contribute to improving the prevention of major accidents in practice.

Looking at the definition of language in the dictionary[1], particular characteristics are interesting for our purpose. Language is a system in itself and important functions concern the communication of 'ideas or feelings'. It has a structuring effect in a system, as it is composed of 'conventionalized signs' or 'marks having understood meanings', thereby connecting those perceiving with some commonness in understanding these conventions and meanings. Thus, our layman understanding of language is that it is a system that supports important processes in a socio-technical system and that influences the functionality of these processes.

Turner (1976), Rasmussen (1997), Perrow (2011), Weick and Sutcliffe (2011), Dekker (2012) and Hollnagel (2014) have all been concerned with recurrent patterns at the source of major industrial accidents. They converge in pointing to assumptions that lie at the basis of risk management practices, and in institutional settings, reinforcing and maintaining erroneous assumptions. These are systemic issues that are often difficult to expose through traditional risk assessments, accident investigations, performance monitoring or audits. It is therefore interesting to look at how language contributes to forming assumptions and processes in risk management practices and how it contributes to common beliefs.

CONTACT Ingrid Årstad ingrid.arstad@ptil.no Petroleum Safety Authority Norway, P.O. Box 599, 4003 Stavanger, Norway

Power (2007) argues that the management of risk critically depends on systems of representation. Language is such a system and it permeates the representations of most aspects of a socio-technical system. Language can therefore inform about risk management practices, their environment and their dynamics. It makes provision for discussing the framing of current accident prevention practices, what is in the framework and what is not, who is in the framework and who is not. It enables assessments of the perspectives and models in use, of assumptions, expectations and aspirations, of beliefs and values.

The primary aim of this article is to demonstrate that Dekker (2012) makes a pertinent recommendation when calling for a language of complexity, and we propose to articulate some characteristics for such a language. We are particularly concerned with language in its context, how language affects and reflects the framing of risk management practices and their improvement. We want to demonstrate how language can be used in practice for clarifying the limitations of current risk management practices and targeting beneficial tweaks and complements. Our assessments include:

1. The content of language, including the words and expressions that are used and *not* used in current practice, how words are perceived and how accurate language is with regard to categorizing and prioritizing.
2. The functions of language, including who uses language that is deemed important for the prevention of major accidents and for what purpose, as well as the language used in norms, models and heuristics.
3. The dynamics of language, including the context in which language is spoken and its ability to support disruptive intelligence in the system.

Although the assessments and conclusions are deemed relevant for any high-risk industry, examples from the petroleum industry have been used.

The remainder of the paper has been organized as follows: Section 2 summarizes how we have approached our subject and what sources we have used as central references in our work. We argue for considering language as a marker of institutional settings and as a marker of disruptive intelligence. In Section 3, we demonstrate how language may affect risk management practices and, in particular, their ability to address the complex nature of major accidents. In Section 4, we discuss on this basis how being aware of language may improve the prevention of major accidents and we propose 10 angles of approach to this effect. The final Section 5 provides some conclusions.

2. Method

We use a qualitative approach that only considers language from the perspective of safety science. We limit our scope on how language may highlight or obscure what is relevant and significant for preventing major industrial accidents, and how language may be instrumental in bridging gaps in existing risk management practices.

Given that major accidents are emergent phenomena in complex systems, we considered literature that informs about the nature of such phenomena and the challenges these may represent, both in general and in regard to the prevention of major accidents. For example, our assessments are based on literature from Perrow (2011), Weick and Sutcliffe (2011), Dekker (2012) and Hollnagel (2014). We use an understanding of the notion of risk, which is adapted to the management of complex systems, in line with Aven (2012) and ISO 31000:2009 (2009a,b). Accordingly, risk contributions are deemed to emerge continuously from the system, its environment and from how risk is recognized, understood and managed. Risk management is considered to be integrated in other management processes and concerned with the challenges inherent to the management of complex systems, as described by March (1994, 1999), Snowden (2005, 2011), Page and Miller (2007), Power (2007) and Mintzberg (2013).

Literature is used to identify convergent core themes and concepts that may lie at the source of systemic issues. This provides a selection of topics that current practices may benefit from assessing. This justifies, for example, a focus on issues linked to system boundaries, linearity, contextualization, integration, adaptation or self-reinforcement. It explains why we direct attention to assumptions relating to cause and effect relationships, knowledge and management objectives. It explains why we look for dysfunctions such as 'chasing out disorder and uncertainty, looking for completeness, separating what is linked, unifying what is diverse and maintaining a binary judgment (either/or)', as summarized by Morin (2008). Thus, the literature gives us both the language and references needed to frame our approach for linking the question of language to the prevention of major accidents.

We also need some references for characterizing the language used in risk management practices. To this effect, we use the current guidelines of the International Association of Oil and Gas Producers (IOGP), ref IOGP1(2008), IOGP2(2011), IOGP3(2013), IOGP4(2012), IOGP5(2014), IOGP6(2016). These are international standards for what is considered good practice in a global high-risk industry and are assumed to reflect up-to-date standards as they have all been confirmed or issued after a major accident (DWH in 2011). The selection of topics in our study is derived from the above-mentioned literature, which relies on empirical studies that are not confined to the oil and gas industry. The selected topics concern systemic issues about the prevention of major accidents, not technical or operational issues in a particular industry. On this level, practices in the oil and gas industry appear fairly representative of practices in other high-risk industries.

The study of language is a vast domain that encompasses many different fields of expertise that are not covered by this article. This article does not consider the semiotic aspects of language in risk management practices. Thus, the methodical approach is not one of document and discourse analysis, as referred to by Gee and Handford (2012). Although the meaning conveyed by some words and expressions and how these are perceived in practice is discussed, this is not a formal study of syntactics, semantics and pragmatics. When contemplating the recommendation of Dekker (2012) to develop a language of complexity, we have considered language from the perspective of safety science, limited to the language linked to the prevention of major industrial accidents.

Although lacking expertise in semiotics and linguistics, we still require some kind of understanding of language in order to be able to discuss it in relation to risk management processes. We understand language as a system that supports important processes in a socio-technical system and that influences the functionality of these processes. We note, for example, that Cilliers (2002), Morin (2008) and Dekker (2012) consider language to be a system of representations, such representations being the result of a web of processes in an open complex system. Language is understood to be a medium for intrapersonal communication (conceptualizing, thinking, reflecting, sense making, judging) and for interpersonal communication (more or less intentional transmission of representations – signal, inform, signify, instruct, argue, share, connect, involve).

As reported by Meadows (2013), 'we don't talk about what we see; we see only what we can talk about', and although language cannot reflect a uniform model of reality throughout an entire socio-technical system, nevertheless, it reflects areas of commonality in the system. Language is the vehicle for interactions between shared and personal representations and it supports both shared and individual representations of assumptions, expectations, aspirations, ambitions and identities. Language can be viewed as a marker of institutional settings that condition risk management practices, reflecting and affecting a shared history, shared experiences, shared models, shared beliefs and values.

3. How language may affect risk-management practice

In this section, we demonstrate that Dekker (2012) makes a pertinent point when he directs attention to the importance of language in safety issues. We show how language may affect risk-management practices, and in particular their ability to address the complex nature of major accidents.

All assessments in this section examine the language used in artefacts of current practices such as norms, standards or accident investigation reports, and appraise it in relation to references in literature or empirical studies that reflect knowledge that is deemed reliable and compatible with the complex nature of major accidents.

3.1. The vocabulary

We start by addressing how risk-management practices may be affected by the existing vocabulary and by the absence of certain words. Words matter because they convey concepts, support representations, affect understanding, assumptions, expectations, aspirations, and reflect models and institutional settings. They may lie at the source of misunderstandings and mislead awareness, as well as affect judgements of values, categorization and prioritization.

3.1.1. The existing vocabulary

A first angle of approach is to consider how crucial words are used in current practices and how they affect the framing of risk-management practices.

It may, for example, be judicious to look more closely at the word 'event' as this word influences many aspects of risk management. Some practices may impose dysfunctional restrictions on the prevention of major accidents by limiting the notion of an event to a pre-defined list of initial accidental events that may occur at an installation, addressing, for example, design or operational issues with a well, process equipment, piping, electrical systems, ballast systems, positioning systems, lifting equipment, etc.

By contrast, the notion of an event could be used in line with its definition in ISO 31000:2009 as 'occurrence or change of a particular set of circumstances'. This sets a wider framework on risk management as it conveys an understanding that events are not necessarily pre-defined and do not necessarily occur at an installation. It allows for recognizing the installation as an open system, thereby acknowledging the importance of occurrences or changes in institutional settings, or in what ISO 31000:2009 refers to as the internal and external context of a system. This means paying more attention to risks inherent to the external environment in which organizations seek to achieve their objectives. These may concern the cultural, social, political, legal, regulatory, financial, technological, natural and competitive environment in which high-risk companies conduct their business. This also means paying more attention to risks induced by internal issues, such as policies, objectives, strategies, processes, capabilities (resources and knowledge), communication, relationships, culture, norms, beliefs, perceptions and values.

Considering existing practices, it may become apparent that the notion of an event is, in effect, also limited to acute, unlawful, unwanted and unplanned events or a chain of events that may cause loss of life or damage to health, assets or the environment. Here again, the definition in ISO 31000:2009 allows for a wider framing, as an event is not necessarily linked to the occurrence of something acute, unlawful, unwanted and unplanned. It may consist of something that is *not* happening or that is happening slowly, and it may consist of something unwanted and unplanned by some but wanted and planned by others. Furthermore, an event does not necessarily have the direct potential of causing loss of life or damage to health, assets or the environment. An event may have the potential of damaging the institutional settings that enable the prevention of major accidents.

Other words that have often been highlighted as critical are 'cause' and 'effect'. These may be used in a way that exaggerate the prevalence of linear, proportional and predictable cause–effect relationships and ignore contextual influences, recursive effects and emergent phenomena. This may also affect the use of the words 'error' and 'non-compliance' by current practices. Management systems may be defined as the cause of errors and non-compliance and indicators of good management would be the absence of errors and non-compliance.

Such an approach may be limiting because normal occurrences may be defined as errors and defined errors may trigger interventions in order to comply with pre-defined norms that may not be realistic or

relevant. Gaps between the intended and the actual outcomes of decisions, between planned and actual interventions, or between work as imagined and work as performed, may be defined by default as safety issues. They may be reduced to errors of management and handled by default by increasing constraints, norms and controls. Thus, how these words are used in practice may demonstrate a way of thinking, systematically idealizing what is knowable, predictable and controllable. This may encourage an over-reliance on technical and administrative constraints, on compliance and control, promoting complacency and passivity. It may also hinder improvements and adaptation of current practices, as the prevention of major accidents would be limited to predicting, norming, complying, controlling to identify errors or non-compliance, and rectifying back to the pre-defined norms.

Disrupting the comprehension of existing words may be necessary. This could be supported by adopting more appropriate definitions (the definition of 'event' in ISO 31000:2009, for example) and/or by complementing the existing vocabulary with new words that enable a better framing of risk management practices. Ackoff (1999) uses the concept of producer-product in order to avoid the limitations of cause–effect relationships. Hollnagel (2014) proposes looking for concurrences rather than causes and to treat them as normal in order to focus on the need to adapt to *what is*, instead of pursuing *what should be*. Snowden (2011) talks about the system's dispositions with the intention of emphasizing 'the evolutionary potential of the present rather than seeking to achieve an ideal future state'.

3.1.2. The missing vocabulary

A second angle of approach is to consider what words are *not* used in current practice and where it is beneficial to enrich the existing language. Terms like 'risk owner', 'risk source' or 'risk attitude' are used in a risk-management standard such as ISO 31000:2009 but they may not be familiar within safety management practices. The notion of risk ownership is useful for addressing agency in the prevention of major accidents. Paving the way for questions about who owns what risks allows for the mobilization of resources that are appropriate for recognizing and handling a sufficiently wide range of risks. It also allows for the clarification of what needs to be common across risk owners and what needs to be different, what needs to be pre-defined and what needs to be left to the discretion of a risk owner.

The notion of risk ownership promotes a responsible culture as it posits each individual and entity as part of the problem and part of the solution for preventing major accidents. It also promotes a just culture by positing some individuals and entities as pivotal because they decide upon the framework conditions for many other risk owners. It promotes self-assessments, actualizing questions about the risks ***I*** own, the risks ***I*** am responsible for recognizing and managing, the risks ***I*** reduce, the risks ***I*** take, the risks ***I*** induce through ***my*** decisions, the lessons ***I*** need to draw from an accident, given ***my*** responsibilities in the system.

The notion of risk source is also useful. It concerns 'an element which alone or in combination has the intrinsic potential to give rise to risk'. It makes provision for addressing risks inherent to events in the internal and external context of a system, whether it is an operation, installation, entity or company. This may be useful for dedicating attention to institutional settings that allow or suppress the emergence of major accidents and may help clarify the role of different risk owners. It also makes provision for addressing risks inherent to the language that permeates risk-management practices.

The notion of risk attitude defines an organization's general approach to risk, i.e. its general approach to 'whether or not risks are taken, tolerated, retained, shared, reduced, or avoided, and whether or not risk treatments are implemented or postponed'. This term is useful for addressing framing issues and the pivotal role of some risk owners in shaping beliefs, attitudes, behaviour or values that permeate risk management practices. It is also useful for articulating the notion that risk management is about taking risks as much as reducing risks, including in matters that concern the prevention of major accidents. Reducing a particular risk implies taking a risk, for example taking the risk of not reducing another risk; taking the risk of reducing the 'wrong' risk taking the risk of reducing the 'right' risk inappropriately; taking the risk that reducing the 'right' risk appropriately will have limited relevance over time; taking the risk of

inducing a new risk, etc. Recognizing the limits and instability of what is known and controlled is definitely valuable for avoiding complacency in risk-management practices.

Taleb (2012) uses the word 'iatrogenic', drawing attention to the negative consequences of a treatment, such as the side effects of a medicine, for example. The best-intended interventions may become toxic to a system safety. Some practices may, for example, overly rely on improving barriers at the sharp end of the business, thereby obscuring and consolidating systemic issues, limiting the effectiveness of intended improvements and unnecessarily complicating operations. The notion of iatrogenic is one that may be useful for avoiding complacency in risk-management practices, by encouraging awareness about the behaviour of complex systems and the emergent nature of major accidents. It may help disrupt eventual rigidities that reduce major accidents to component failures, seeking to prevent them by addressing one event and one barrier at a time, as though the performance of a socio-technical system resulted from the performance of each component individually. It may help disrupt eventual rigidities that focus awareness on the risks reduced and deflect awareness from the risks taken and the risks induced. It may help disrupt eventual rigidities that idealize the upsides of risk management and ignore that risk management practices are also a risk source.

Conceptualization cannot be unified, either with or without new words and new definitions. Furthermore, new words are seldom sufficient for changing existing understanding. However, the introduction of new words and new definitions permits reflections and processes that often result in *some* beneficial disruption of existing knowledge, perceptions or judgment.

3.1.3. Expressions

A third angle of approach is to consider whether some expressions may create misunderstandings. For example, mentions like 'in the operation', 'in the activity' or 'on the installation' may be predominant in norms pertaining to accident prevention and, in some areas, these redundancies may be dysfunctional. This could establish a belief that problems and solutions in system safety issues are confined to the lowest levels of a socio-technical system, thereby justifying business as usual in the rest of the system, with the cementing of systemic issues that this entails. It is therefore pertinent to verify where such mentions are pertinent and where they are not pertinent.

It may also be useful to consider the expression 'risk of a major accident'. While it is a practical expression in risk-management conversations, it may reflect or create misunderstandings about the nature of such accidents and about their management. It may convey ideas that are incoherent with the complex nature of major accidents. For example, it may convey that a major accident is the result of the conjunction of component failures, that the risk of a major accident is tractable as such, that a risk analysis can offer an adequate representation of that risk and that this representation is functional for taking the decisions necessary to prevent a major accident. These are oversimplifications, as major accidents are system issues, the risk of a major accident is not tractable as such and a risk analysis cannot offer an adequate representation for preventing emergent phenomena. The prevention of a major accident cannot rely on sequential formal analyses alone as it depends on continuous interventions and interactions in a socio-technical system. The notion of 'risk of a major accident' will not characterize a precise risk, but the potential resultant of these continuous interventions and interactions, many of them independent of each other. Asking what the risk of a major accident might be is a question that may be expected be answered in simple terms, and giving a simple answer may be tempting. However, expecting or giving a simple answer may divert attention from the interventions and interactions that occur in a particular socio-technical system, their inevitable limitations, volatility and contradictions. It may divert attention from the prerequisites for actually preventing a major accident.

3.1.4. The tone of words and expressions

A fourth angle of approach is to consider how words are perceived in current practices. Some words are perceived as words that concern something beneficial to the prevention of major accidents, while other

words are understood to characterize negative aspects of system safety. Words such as simple, standardized, unified, predictable, control, compliance, order are usually perceived positively. By contrast, words such as complex, error, unexpected, improvization, different or diverse may not be perceived as positive, but rather as symptoms of a lack of control, issues that require a certain amount of correction. The tone of words and expression reflects and affects the framing of risk-management practices, what is considered normal, desirable and achievable. Such perceptions may have a detrimental effect on risk-management practices.

It is, for example, dysfunctional to treat 'complex' as a problem that requires fixing, instead of treating it as crucial information about the unfixable characteristics of the system that requires managing. Treating the terms error, unexpected, improvization, different or diverse as problems that require fixing may be appropriate in simple and complicated domains, but this is dysfunctional as a general rule in the complex domain, where emergent phenomena such as major accidents belong. This would convey a notion of management reduced to a 'plan-do-check-act', understood as a predictable sequential and formalized approach, and emphasizing the administrative aspects of management. This would convey the idea that a tractable safety state could be shaped with appropriate tools, with documented norms and pre-determined practices, and by means of constraining, directing and controlling human resources to 'do things right'. This would increase bureaucracy, complicate interactions and install rigidities that hindered adaptation, learning and development.

Norms pertaining to the prevention of major accidents tend to expect the demonstration of risk oversight and risk control, as well as demonstration of risk and uncertainty reduction to as low a level as is reasonably practicable. They may not expect the demonstration of a chronic awareness, of understanding the limits of current risk overviews and controls, of understanding risks taken and risks induced, although this is highly relevant for effectively avoiding a major accident. The injunction to 'demonstrate' risk oversight and control may be perceived as being positively laden, while the terms 'risk' and 'uncertainty' may be perceived as negatively laden. Thus, practices may favour tools that measure risk and uncertainty, and reducing representations of risk and uncertainty may become the main objective to pursue. This paves the way for misunderstandings about the extent, objectivity and stability of risk oversight and control.

The tone of words and expressions may also divert attention from considering crucial knowledge as relevant to the prevention of major accidents. Talking about learning from failures is perceived positively and obscures the need to consider learning to fail, as well as experimentation. Discussions about improving overview and control may prevail at the expense of discussions about adaptive capabilities and the need for slack highlighted by March (1994), as well as scholars concerned about systemic accident models.

3.1.5. Distinction-making

A fifth angle of approach is to consider whether the language in use is precise enough and allows for categorizing and prioritizing.

Language allows for articulating different characteristics more or less precisely. Some words are useful but not precise enough. For example, the word 'bird' does not communicate the difference between an albatross and a raven. Weick (2012) addresses this issue by drawing attention to the safety criticality of 'distinction-making'. It is therefore relevant to consider how coarse or fine-tuned the language in use may be and whether it could be beneficial to increase the level of precision.

It is, for example, crucial to be able to distinguish between 'complicated' and 'complex', as it permits characterizing a challenge, making reasonable assumptions, choosing appropriate models and avoiding unnecessary complications. Being able to distinguish a linear from a non-linear phenomenon is useful, because it permits a more precise understanding of the nature of the challenge and making appropriate choices. Distinguishing the means from the ends is useful for avoiding dysfunctional 'tick-the-box' approaches to system safety. Being able to distinguish a robust solution from a resilient one is useful, as they respond differently in the face of harmful influences, address different needs and offer different forms of protection. Being able to distinguish accident from accidental risk is useful to avoid treating accidents

or their absence as risk indicators. Being able to distinguish risk from risk representations is useful for avoiding an over reliance on predictive tools, underestimating the pervasive and dynamic nature of risk and repressing the integration of risk management. Being able to distinguish analysis from management is useful to avoid limiting risk management to the use of risk analyses, thereby disconnecting risk management from other processes. Being able to distinguish aggregation from integration is useful for disconnecting the right processes or for understanding the limitations of sequential risk analyses and aggregated performance records. Being able to distinguish effectiveness from efficiency is useful because it affects the values and ambitions underlying risk-management practices. Being able to distinguish what is necessary from what is sufficient is useful for understanding the limits of risk overviews and controls. Being able to distinguish systemic from idiosyncratic issues is useful because they require the intervention of different risk owners and different kinds of solutions. Being able to distinguish between wants, needs, musts and cans, permits getting priorities right among relevant choices by enabling a focus on needs and functions rather than preferences.

3.2. The functions

Looking at norms, tools, processes and objectives is about looking at what the language is used for, what functions it supports. This informs about what current practices deem as being necessary to rely on and carry out in order to prevent major accidents.

3.2.1. The users and the usage

A sixth angle of approach is to consider who uses language that is deemed important for the prevention of major accidents and to what use the language is put. A language is instrumental in connecting individuals and entities about what is deemed necessary. Important information about current practices may be identified by looking at which interactions are believed to be relevant for the prevention of major accidents and what these interactions concern. What is considered to be a safety-related conversation and who engages in such conversations? This may demonstrate that interactions about the prevention of major accidents are mainly vertical and that conversations that are deemed relevant primarily concern the design and operation of installations, including related errors, non-compliance and incidents. It may reveal that a lot of processes are not considered relevant to system safety, for example, processes about how to adapt to a financial and industrial context, about strategic decisions, about contracts and alliances, processes aimed at improving cost-effectiveness, about regulations and regulatory controls, about lobbying and communication strategy, etc.

It may demonstrate that some individuals and entities concern themselves with what others do with system safety, what others should do, what others should learn, and that they pay less attention to their own performance in their role and function. Some may believe that they do not work with issues that are relevant to system safety and are not aware that what they do impact crucial framework conditions for what happens on installations. It may reveal a pervasive belief that issues concerning system safety are disconnectable from other matters and the concerns of safety specialists, risk analysts or those working with issues concerning technical, operational or organizational issues on the installations. It may become apparent that what the organization believes it knows about system safety relies heavily on indicators that concern performance in operations. This would reveal the need to address fundamental assumptions about current practices and to develop information about institutional settings in order to be able to address systemic issues and avoid burdening operational levels with dysfunctional constraints.

3.2.2. The norms

A seventh angle of approach is to consider the language that characterizes the norms that are deemed crucial for preventing major accidents.

It may, for example, be useful to consider the language used in norms that address the types and functions of the risk assessments that are deemed relevant, and the conditions deemed necessary for ensuring the functionality of such assessments.

These norms may use certain elements of vocabulary mentioned earlier and create significant misunderstandings about the information effectively provided by such tools. This concerns, for example, the terms 'event', 'risk of a major accident', 'cause and effect'.

How the notion of risk analysis is distinguished from the notion of risk management may inform both about how current practices understand the notion of management and risk management. It may be particularly informative to look at how they position the notion of risk analysis in relation to the notions of management tools, enablers, processes and objectives, stakeholders, internal and external context. This may lie at the source of oversimplifications, such as limiting risk management to risk assessment and narrowing contextual considerations to what matters to a particular risk assessment, instead of what matters for system safety and management purposes.

The name of tools that appear in norms may be as follows: event trees, FMEA (failure modes and effects analysis), HAZID (hazard identification study), HAZOP (Hazard and operability study), design review, QRA (quantitative risk analysis) or TRA (total risk analysis). The extent of the limitations of these tools with respect to the prevention of major accidents may be unclearly formulated. This could lead to a significant blind zone in risk management practices by creating the impression that these tools have the potential to enable an appropriate understanding and handling of the risk of major accidents. It may reinforce a number of dysfunctional beliefs. For example, it may reinforce the assumption that major accidents are component failures that accidental risks are confined to the design and operation of installations and that such risks may be understood and handled appropriately regardless of how the rest of the business is conducted. Emphasis on analytical processes may reinforce tendencies to zoom in on details regardless of contextual influences, thereby obscuring systemic issues, with the risk of repeatedly treating the wrong problems.

Emphasis on formal, sequential processes may over-communicate risk management as a technical issue and under-communicate risk management as integrated in what agents do in a socio-technical system. This may overexpose certain agents and processes at the expense of others. Improvements to risk-management practices may emphasize what risk analysts, experts and decision-makers could improve in risk-assessment processes, and focus mainly on top-down improvement processes. This may obscure what other agents could improve, how to improve the conditions for prudent agency in the system and what any agent could improve in own sense-making and interventions, wherever they are in the socio-technical system, and whoever they are. Emphasis on formal processes may under-communicate the value of informal processes in complex systems. It may divert attention from the need for agents to *recognize* risks in practice, continuously, in real time, in a dynamic environment and with limited foresight, including in the absence of risk analysts and without a pre-defined recipe that describes how risks should be recognized, labelled or handled, including without leaving written traces. This may reinforce the externalized processes of risk management at the expense of internalized reflective processes, emphasizing what Weick (2012) calls knowledge by description, at the expense of knowledge by acquaintance, which enables context-relevant insight, paying attention to changes, unexpected events or patterns, new or unfamiliar cues.

Through their focus on concepts such as 'acceptance criteria' and 'ALARP', the norms may convey the idea that risk cannot be managed if it is not duly labelled as such and explicitly expressed. This may limit risk management to a series of sequential formal processes for devising the necessary risk expressions and limit the enhancement of risk-management practices to improve the models, data and tools used to express risks. This may under-communicate the fact that risk sources and events emerge independently of our ability to describe and document them, that many risks do not 'wait' to be analyzed and handled before they pose a problem and that risk management is not meant to 'stop' between risk analyses.

3.2.3. The representations

An eighth angle of approach is to consider the representations conveyed by the language used in current practices. As highlighted by Power (2007), managing risk critically depends on systems of representation and framing instruments. For example, quantitative risk analyses use probabilities to express risk, and what such risk measures are believed to represent is critical. It may appear that current practices do not distinguish between risk measures and risk, and view differences between risk measures before and after risk reduction as evidence of risk control. Assuming that both the risk of a major accident and the effect of barriers to that risk are knowable encourages complacency and reflects what Power (2007) calls a calculative 'grammar' of risk management. It conveys the idea that risk and safety are commodities and justifies acting as if one knows how much safety one has, how much more one needs and when one has a sufficient amount of safety. This makes provision for an accounting approach to system safety, in which the cost of a safety measure is deemed justified based on its calculated impact on a calculated risk.

It may also be informative to look at what established performance indicators are believed to represent. It may reveal that incidents and non-compliance are viewed as reliable indicators of risk and risk-management performance. This would entertain the belief that what has happened up to now in the system is representative of what may happen going forward, and the absence of occurrences up to now could be viewed as a good omen for the future. This would make provision for a reactive approach, in which no improvements to safety practices are deemed necessary before evidence of failure exists.

The visual representations used in current practices may be informative. For example, the bow-tie model gives a visual representation, which has been widely used in risk-management practices in the oil and gas industry since the Piper Alpha accident in 1988. It supports discussions about accident scenarios, plausible issues and relevant preventative or mitigating solutions. It may be useful to consider how it is used in practice in order to clarify whether and where a disruption may be beneficial. It may appear that they are centred in practice on a generic list of accidental events that may occur on installations, and on certain particular consequences of such events, and that they support discussions about the statistical occurrence of events and failure rates of different barriers, both before and after improvement measures have been implemented. This may be intentional and it is therefore pertinent to look more closely at how models are selected and how information from such processes is used. This may reveal that current practices do not discuss contrasts between different domains and therefore use models to address complex issues that are only appropriate in simple and complicated domains. The bowtie model is appropriate where the machine metaphor is applicable, for addressing component failures and cause-effect relationships, but offers no help in discussing issues that may emerge from independent events, occurrences and circumstances.

3.2.4. The rules of thumb

A ninth angle of approach is to consider whether the language that permeates current practices expresses rules of thumb that are coherent with the aspiration of preventing a major accident. As major accidents are system accidents, they depend on functional agency and functional interactions between different agents in a socio-technical system. Although it is crucial that individuals and entities adopt a language that corresponds to their respective area of responsibility and functions in that system, common representations are necessary to enable beneficial coherence. Looking at rules of thumb in current practices informs about common representations of how major accidents are understood and what is deemed relevant, normal, desirable, adequate, sufficient, sustainable, certain, knowable, controllable, tractable, etc. Rules of thumb support what we think per default and, as highlighted by Kahneman (2011), this includes when it is necessary to switch to a more reflective and active mode. Thus, rules of thumb are necessary simplifications and necessary rigidities, but they are beneficial in our context only when they are coherent with the aspiration of preventing major accidents.

Current rules of thumb may rest on limiting associations, such as limiting major accidents to component failures, limiting risk management to the performance of formal risk assessments, limiting risk to risk expressions or limiting system boundaries to the lowest parts of a socio-technical system. They may rest on the assumption that what matters to system safety is labelled as such, thereby systematically disconnecting the prevention of major accidents from managing the business in a high- risk company.

Current rules of thumb may also create limiting associations. For example, they may support a binary approach to risk reduction and not support contextualizing. Discussions about reducing risk may automatically consider increasing restrictions and formalities, without considering the possibility that fewer restrictions and fewer formalities may be more appropriate. Agents may automatically consider more norms and more detailed norms, not less norms and more functional norms, and may systematically examine the option of more unification, not more diversity. They may automatically direct risk reduction within the system boundaries of the risk analysis and systematically neglect systemic issues or the option of obliquity discussed by Kay (2011). Targeting recruitment in a support function may give better results than writing a new operational procedure, just like targeting hunger may give better results than chasing calories.

Current practices may appear to be dominated by 'either/or' considerations and 'whether-or-not' questions, showing a propensity for binary thinking and de-contextualization. For example, a practice may be more apt to consider whether a subsea detection system is necessary and expect a clear answer (either necessary or not), instead of asking by default 'when' it will be necessary, considering that it might be necessary in certain situations, but not necessarily in all situations. Many choices cannot be pre-defined and must remain open to both one option and its opposite. Binary thinking and de-contextualization are oversimplifications that make provision for the use of standardized solutions where inappropriate and obscure the need to adapt and continuously strike a balance between contradictory needs. It is, for example, necessary to continuously balance risk control and risk taking, prediction and improvization, balance centralization and decentralization, control and trust or formalization and non-formalization. System safety is not a choice between a robust and a resilient system, as both robustness and resilience are necessary in complex systems. Robustness is needed to sustain and resist negative effects and resilience is needed for adaptation or transformation when confronted with multiple negative effects or disturbances.

It may appear that some issues could benefit from heuristics that encourages a more functional approach. Given the dangers of an expression such as 'the risk of major accidents' mentioned earlier, some questions may be asked per default. For example, questions such as 'risk of what?' may be useful for bringing clarity to risk management, communicating what has been addressed and what remains to be considered. It may help reveal a wider range of potential consequences for the same events, compared to what may be the case in risk analyses. The same events could, for example, pose a threat to the workforce, the environment, assets, production, flexibility or reputation. This may help expose the multiple functions of particular barriers, thereby better understanding their importance, and provide a stronger argument for the priority they deserve. Questions such as 'risk to whom?' or 'low risk to whom?' may reveal critical information, help take into account internal and external stakeholders better, shed light on a wider range of consequences and help consider problems both in the shorter and the longer term. Asking certain questions by default may also improve the appraisal of uncertainties and ambiguities and combat complacency. Questions about the advantages of decisions may be coupled to questions about their disadvantages, and questions about what risks are being reduced may be automatically coupled to questions about what risks have been taken and what risks are being induced. Conversations around performance indicators may systematically address what these do and do not inform about.

3.3. The context in which the language is spoken

A tenth angle of approach is to consider the context in which the language is spoken in order to clarify the current conditions for disruptive intelligence in the system. Disruptive intelligence is a term generally used when considering the conditions for adapting a business to innovations that have the capacity to

dramatically transform the business. It is also a term that may be functional in safety management practices, as Turner (1976) characterizes major accidents as large-scale intelligence failures and focuses on the need to disrupt the conditions that allow such accidents to occur. The language that permeates current risk-management practices may inform about the system's ability to question what needs to be questioned and disrupt what needs to be disrupted in order to avoid system failure.

By approaching major accidents as system failures rather than component failures, the functional performance of the entire socio-technical system becomes more important than an idealized, error-free performance of its parts. It is therefore useful to assess whether the language that permeates current risk-management practices exhibits tendencies to disconnect what is connected. This may be apparent in risk assessments, when encouraging risk assessments that focus on one operation at a time, one installation at a time, one type of risk at a time, one risk-reducing decision at a time, one risk at a time, one perspective at a time, etc. It may also be apparent in investigative processes, when focusing on one accident on one installation at a time, or in norming processes, when addressing one barrier at a time or one barrier function at a time. Such de-contextualization, disconnection and isolation of issues may be an institutionalized obstacle to beneficial disruptions.

Considering organizational structures may be pertinent, as they both reflect and affect the functionality of institutional settings. They may, for example, consolidate a language that disconnects safety and environmental issues throughout the system, maintaining institutional settings that obscure the benefits of balancing investments in accident prevention and damage control.

The language used in norms may create institutional settings that do not encourage important types of disruptions. Norms pertaining to investigations after incidents and accidents may limit the scope of investigations, narrowing the insight to parts of a socio-technical system and thereby actualizing fewer, less effective disruptions. They may favour disruptions at the sharp end of the business and reinforce dysfunctions at the blunt end of the business. Norms pertaining to risk management may not address risks inherent to the language that permeates risk-management practices. They may therefore encourage disruptions that affect technology and procedures rather than disruptions of assumptions, expectations, aspirations or interactions. They may motivate the system to focus on compliance with norms and standards rather than on functionality in context and on coherence with the aspiration to prevent a major accident.

Disruptive intelligence is not only about disrupting what is dysfunctional with respect to the prevention of major accidents, it is also about conserving what is functional. It is about distinguishing between what is functional or dysfunctional at a system level, not at a component level. Some agents at the blunt end of a socio-technical system are pivotal to institutional settings. Corporate management and the safety authorities are in such a position. The language they use is a significant risk source, as it will have a major impact on the language used by many other agents in the system and on their motivation to balance disruption and conservation at their level. Furthermore, interactions between pivotal agents are crucial for balancing disruption and conservation in institutional settings.

Given that the prevention of major accidents concerns agency in a socio-technical system, the diversity of the language in such a system informs about institutional settings. Are there many 'dialects' in the system? If the language for appraising the relevance, criticality and stability of risks is unified across a system, this is a sure sign of dysfunctional settings. For example, it would create a significant blind zone in risk management if the different levels of a socio-technical system were to discuss the same performance indicators, as it would divert too many agents from appraising performance within their own area of competence, influence, and responsibility. Institutional settings with a uniform language would not only be unfavourable for mobilizing and connecting the range of risk owners needed for recognizing and handling the range of actual risk sources in such a wide system, they would also repress beneficial disruptions. Critical thinking, the confrontation of different perspectives and disagreements are necessary for preventing major accidents. Different 'dialects' are necessary for enabling beneficial disruptions. Weick and Sutcliffe (2011) encourage to be mindful of labels and expectations, thereby advocating critical thinking, remembering that complex systems are dynamic and may require a departure from currently accepted labels and routines. As discussed by Aven and Renn (2010), it is necessary to address risk from different

perspectives, economical, technical, operational, administrative, cultural or psychological. Different risk owners need different tools and different perspectives on risk in order to be able to address the risks that are relevant to them, given their role and function in the socio-technical system. The confrontation of different perspectives and different interests is the confrontation of different "dialects" that concern the prevention of major accidents, and acts as a fertilizer of institutional settings, whether or not an individual confrontation results in agreement, implies misunderstandings, or results in an adequate decision.

Given the diversity of perspectives and interests in a socio-technical system, it is inevitable that words spoken in a particular context have a tactical rather than an informative value. This may blur the picture of what needs to be conserved or disrupted. For example, if certainty about overview and control of the risk of a major accident is expected, certainty may be fabricated to fulfil expectations, rather than to describe the actual insights and risk management interventions. Thus, what is said 'on stage' may vary from what is said 'off stage'. This difference may be intentional, and it may also be beneficial. What is disrupted and conserved 'on stage' may differ from what happens 'off stage', and in some cases what happens 'off stage' should be different, in order to be coherent with the aspiration of preventing a major accident.

4. The language of complexity in practice

Dekker (2012) posits language as an instrument for improving the premises of existing practices, so that they reflect the complex nature of major accidents. He particularly highlights the need to become 'more open to the complexity, the dynamics, erosion and adaptation that marks socio-technical systems'.

4.1. Language as a framing instrument

Dekker (2012) is concerned that current risk-management practices do not appropriately address the complex nature of major accidents. This concern is shared by many, including Perrow (2011), Rasmussen (1997), Weick and Sutcliffe (2011) and Hollnagel (2014), and the relevance of this concern is confirmed by many investigative reports, for example, after the Texas City explosion (TC 2007 a, b) and DWH (2011, 2016). Recurrent questions appear to be concerned about whether, in practice, major accidents are treated as though they were component failures, as though their prevention relied on preventing component failures one by one, and as though component failures at installations could be prevented in isolation from their context.

An acceptance that major accidents are emergent phenomena instead of component failures imposes a much wider framing for what the prevention of major accidents requires. This directs attention to crucial issues, such as how current practices set system boundaries, what is defined as relevant to the prevention of major accidents within these boundaries, what uncertainties are taken into account, what is believed realistic to achieve and whom is deemed important to mobilize.

These issues have been at the core of the method applied to this article (ref. Section 2), at the core of the questions assessing how language may affect risk-management practices (ref. Section 3) and at the core of the 10 propositions outlined in Section 4.3. Language can indeed be an instrument for framing current practices and for assessing how well they reflect the systems thinking approach necessary to preventing major accidents effectively.

4.2. Language as a safety monitoring instrument

By positing language as a framing instrument, Dekker (2012) also posits language as a safety monitoring instrument. If language reflects framing conditions, then language reflects more or less functional conditions for preventing the emergence of a major accident. Language is therefore a useful marker of limiting perspective and can be used to expose systemic dysfunctions in risk-management practices. Thus, it makes

provision for considering other types of safety indicators than traditional safety indicators based on accounts of non-compliance, incidents and accidents.

Language and adaptive capabilities: Dekker (2012) highlights, for example, the importance of reflecting 'complexity, the dynamics, erosion and adaptation that marks socio-technical systems'. In this respect it is interesting to note that the same terms have been used in the prevention of major accidents for at least the last thirty years. These are terms such as hazards, events, risk, risk analysis, risk assessment, risk evaluation, risk reduction, risk acceptance, ALARP principle, risk monitoring, barriers and key performance indicators (KPI). These terms have essentially been used in the same way in practice and are currently still at the core of improvement processes deemed necessary in the aftermath of major accidents. The main idea is that the risk of a major accident is deemed knowable on the basis of predictions of hazards and events on the installations, such knowledge is deemed justifiable by the use of risk analyses and KPIs and such risk is deemed controllable through barriers that ensure asset integrity.

The stability of language over time may be a matter of concern from a system safety perspective. Major accidents are emergent phenomena that develop over time in complex systems. As complex systems are dynamic systems, the management of such systems must also be dynamic and adaptive. Language supports representations of reality, and this reality is dynamic. Language may therefore be considered as a marker of the capability of institutional settings to adapt to the context and evolution of the environment.

Language and preparedness: It seems pertinent to question whether the stability of language reflects a degree of inertia in adapting risk-management practices to new risks following technological and societal developments. As early as 1984, Perrow (2011) drew attention to the safety criticality of increasing complexity resulting from automation, globalization, the development of financial systems and new information technology.

The increasing complexity in high-risk industries was confirmed by OECD (2003) and Le Coze (2017). More recently, the so-called disruptive technologies have been much discussed, as these are expected to alter how businesses are conducted, how people interact and how societies function. In this respect, McKinsey (2013) highlights, for example, a number of technologies related to the internet, artificial intelligence, automation, genomics, energy storage, advanced materials, renewable energy, material technology or 3D printing.

These technologies are what Dekker (2012) characterizes as unruly technologies, introducing and sustaining major uncertainties. These developments imply that systems grow in size, the number and the diversity of the functions they serve increase, their ties to and dependencies on other systems increase, the predictability and controllability of interactions and outcomes decrease. While there are a number of reflections for understanding the implications of disruptive technologies for management, such reflections do not seem to address their implications regarding the prevention of major accidents, and practices remain essentially unaffected.

Language and learning: It also seems pertinent to question whether the stability of language reflects a degree of inertia when it comes to improving risk-management practices in the light of experience and lessons learnt from major accidents. Turner (1976) argues that major accidents can be viewed as a 'cultural disruption' in the sense that they reveal a significant disruption of what a system believes about itself, about its oversight, understanding and control. This makes provision for looking for the conditions necessary to disrupt the emergence of such 'cultural disruption'. On this basis, Power (2007) summarizes that a major challenge for the prevention of major accidents is to foster "disruptive intelligence" and eliminate "perfect place arrogance" in risk management. The evolution of language can therefore be considered as a marker of disruptive intelligence, necessary for the disruption of dysfunctional beliefs in risk management practices, identified through the 'cultural disruption' provoked by major accidents.

Language and the health of a socio-technical system: Based on the above, it is relevant to consider whether the stability of language over time may indicate a lack of disruptive intelligence. The first noticeable point is that risk management practices do not appear to become more effective in preventing major accidents. In a report on *emerging systemic risks,* the OECD (2003) demonstrates that the number of 'technological disasters', such as explosions, fires, and transportation accidents, has increased consistently

since the 1970s. It also demonstrates that these accidents have more negative consequences in terms of fatalities and costs, including economic and environmental losses. Similarly, as highlighted by, for example, Le Coze (2013) and DNV GL (2015), no evident progress has been made over the last thirty years in our ability to prevent major accidents. This conclusion applies across very different high-risk industries, including the oil and gas industry.

Considering the investigative reports after the Texas City (TC 2007 a, b) and DWH (2011, 2016) accidents, it is clear that decades of experiencing major accidents within one single company did not help lessen the 'cultural disruption' experienced by corporate management each time a major accident occurred. Nor did it result in beneficial disruptions in the institutional setting framing the prevention of major accidents in the company in question. In 2007, the Baker Panel noted 'A substantial gulf appears to have existed (-) between the actual performance of BP's process safety management systems and the company's perception of that performance'. In the report issued in 2016, the same auto-satisfaction in risk-management practices *ex ante* is exposed, encountering the same bafflement about the magnitude of the gap between beliefs and reality *ex post*. Major accidents do not appear to trigger disruptions at an industry level, either. Following the DWH accident in 2010, the oil and gas industry in the USA continues to resist regulatory changes with the same arguments that have succeeded in blocking regulatory improvements since the Piper Alpha accident in 1988. Major accidents do not appear to function as effective drivers for improving 'disruptive intelligence' within existing perspectives, even though such disruption is needed. Thus, addressing a stable element such as language contains the promise of resolving a number of systemic issues.

In conclusion, the stability of language in risk-management practices over thirty years may be raised as a relevant matter of concern. It may indicate rigidities in institutional settings, adaptation and learning, what March (1996) may qualify as an imbalance between the exploration of new possibilities and the exploitation of old certainties. This brings to light the fact that a functional language is a dynamic language that enables beneficial disruptions in risk-management practices, so that they become and/or remain relevant and effective in a dynamic environment. The recommendation from Dekker (2012) to critically review current practices seems therefore pertinent, in all practices and at any level in a socio-technical system.

4.3. How to assess the language used in current practices?

Dekker (2012) recommends reviewing current practices critically and he posits the language in use as an angle for approaching such a critical assessment. How this can be achieved in practice can follow the same approach as the one we use in Section 3.

We suggest observing the language used in artefacts of current practices such as norms, standards or investigation reports, and appraising it in relation to references in literature or empirical studies that reflect knowledge that is deemed reliable and compatible with the complex nature of major accidents. We recommend that assessments cover the vocabulary in use, the functions of that vocabulary and the context in which the vocabulary is defined, confined and used. We propose the same 10 angles of approach, considering the following:

1. How crucial words are used, and how they affect the framing of risk-management practices.
2. What words are *not* used and where it may be beneficial to enrich the existing language.
3. Whether some expressions may create misunderstandings.
4. How words are perceived in current practices.
5. Whether the language is precise enough and permits categorizing and prioritizing.
6. Who uses the language and how it is used.
7. What the language conveys in the norms that frame the prevention of major accidents.
8. What the language conveys in the models currently in use.

9. Whether the language conveys rules of thumb that are coherent with the aspiration of preventing a major accident.
10. What the context in which the language is spoken encourages or represses.

The appraisal of current practices from different angles through the lens of language provides valuable information about how well adapted they are to the complex nature of major accidents, eventually highlighting where changes are necessary. These assessments can therefore bring current practices in coherence with the aspiration of preventing a major accident. They may encourage a more functional account of the reality that needs managing and a more realistic understanding of what is known and controlled. They may enable the continuous disruption necessary for adapting risk-management practices to new challenges and new knowledge.

Encouraging a language of complexity is not a matter of replacing the existing language with another, it is about expanding this language, widening the array of ideas, words, reflections, conversations and questions in use. The point is to enable the recognition of a wider range of risks, a better and earlier understanding of their relevance and significance, and to consider a wider repertoire of tools, models and measures to appraise and handle risks more effectively.

The language that permeates an organization's practices is also an interesting way of approaching complacency issues. How the language evolves may reflect adaptive and learning capabilities, and it may inform about how concerned an organization is about disruption, where it looks for disruption, as well as the sort of disruption it emphasizes and regards as beneficial.

Furthermore, language not only affects the system, but also reflects the system. Focusing on language may therefore help address systemic issues in the prevention of major accidents. Accepting that major accidents are emergent phenomena directs attention to interactions within the boundaries of a wide socio-technical system. Many different players in this system can benefit from evaluating their own current approach through the lens of language. Improving their own contribution to the system may yield better results than their attempts to change others player's practice.

Assessments across the socio-technical system may also reveal how certain practices may limit the framing of other practices or how practices in certain parts of the system impair the flow of safety- critical information. Focusing on language may help mobilize risk owners more appropriately throughout the system or improve how they take ownership of their risks in practice.

5. Conclusions

This article does not concern language as such, but the functions of language from the point of view of safety science. We identify how language reflects and affects the institutional settings in which this language is spoken, and how it informs on crucial conditions for preventing a major accident. We demonstrate how it informs about current risk-management practices, what is in the frame and what is missing, what is functional and needs to be conserved, what is dysfunctional and needs to be disrupted. We also discuss how it informs about whether an organization views current practices as a risk source, how concerned it is about disruption, where it looks for disruption, as well as the sort of disruption it emphasizes and regards as beneficial. We argue that language is a marker for an organization's propensity for complacency and inertia, both recognized as significant prerequisites for the emergence of major accidents.

We propose 10 different ways of assessing language in current practices and provide many examples of symptoms of dysfunctions and improvement areas that may be identified. We draw attention, for example, to possible limitations in the understanding of common words, such as event, cause, effect and system, or to the possible absence of words that it may be useful to introduce, such as risk source, risk owner or iatrogenic.

A language of complexity is not a separate special language that is only spoken by some agents for addressing particular issues. It is simply the language needed to support a functional agency in a

socio-technical system. A functional agency is functional with respect to many interdependent objectives. Being functional with respect to preventing a major accident cannot be separated from being functional with respect to achieving operational objectives, compliance objectives, financial objectives, environmental objectives, reporting objectives or strategic objectives. A language of complexity supports agents in a system to fulfil their respective functions in coherence with the knowledge that major accidents are emergent phenomena and with the aspiration to prevent such accidents.

Seeking to characterize the language of complexity recommended by Dekker (2012), we conclude that it is a language for 'getting real' in the prevention of major accidents and a language for combating complacency and inertia.

It is a language that defines boundaries for prudent practice by rejecting oversimplifications. It excludes the reduction of major accidents to component failures and confines what matters to system safety to definite parts of a socio-technical system. It rejects the idealization and dehumanization of what needs to be managed. It rejects the application of the machine metaphor to anything and everything. It problematizes oversimplifications and rigidities. It turns down claims or expectations of certainty in risk issues. It rejects the assumption that everything is tractable, objective, stable, knowable, measurable, predictable and controllable, including what people think and do. It directs attention to the normality of imperfection, uncertainty, unsustainability and ambiguity, to the normal limits of what is knowable, controllable and achievable. It is a language for harnessing what 'is' rather than what 'should be'. It recognizes that gaps between 'is' and 'should be' are the norm rather than the exception and that many instances of 'should be' should not be permanent.

It is a language that sets priorities. It emphasizes a continuous search for coherence with the aspiration of preventing major accidents, rather than seeking compliance with norms and pursuing non-compliance. It emphasizes the coherent performance of the whole, rather than the perfect performance of the parts. It encourages contextualization, rather than standardization. It values functionality in context, rather than compliance or conformity. It encourages compliance with needs, rather than compliance with norms. It encourages continuous awareness, rather than sequential formatted assessments. It directs attention to current dispositions and future ambitions, rather than current performance. It emphasizes the necessity of balancing contradictory needs, rather than problematizing contradictions and ambiguities. It encourages rigidities set on values and aspirations, rather than rigidities set on beliefs, assumptions, expectations and particular solutions.

It is a flexible and dynamic language. It has many 'dialects' in order to adapt to the different needs of different agents with different functions in different systems. It evolves in order to reflect changes in the internal and external context of a particular system. It supports disruptive intelligence, encouraging critical thinking, dynamic interactions, diversity, as well as reflective and self-reflective processes.

In conclusion, developing a language of complexity is an ongoing adaptive process that aims to support risk management practices to become, be and stay relevant for achieving an organization's objectives – one of them being to prevent a major accident.

This work gives credit to scholars that have relentlessly sought to direct attention to the necessity, the urgency even, of applying systems thinking in safety science. This article provides a concrete example of how current practices may identify how near or far they are in relation to applying systems thinking at a practical level, and how they can improve in this particular area. It demonstrates that there are many safety assessments that are not assessments of compliance, and many safety indicators that are not based on counting non-compliance, incidents and accidents. Further research is necessary to support practices in their efforts to address systemic issues, including dysfunctions such as 'chasing out disorder and uncertainty, looking for completeness, separating what is linked, unifying what is diverse and maintaining a binary judgment (either/or)' Morin (2008).

Note

1. https://www.merriam-webster.com/dictionary/language.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Ackoff, R. L. (1999). Ackoff's Best: His classic writings on management. Kindle Edition. (Referring to Ackoff R. L. and Emery F. E., 1972 On purposeful systems. Chicago: Aldine-Atherton)

Aven, T., & Renn, O. (2010). *Risk management and governance, concepts, guidelines and applications*. Berlin Heidelberg: Springer-Verlag. ISBN 978-3-642-13925-3

Aven, T. (2012). The risk concept – Historical and recent development trends. *Reliability Engineering and System Safety*, *99*, 33–44. Retrieved from: http://dx.doi.org/10.1016/j.ress.2011.11.006

Cilliers, P. (2002). *Complexity and postmodernism: Understanding complex systems*. Taylor and Francis. Kindle Edition.

DNV. (2015). DNV GL, 2015, Regulatory outlook – The way forward for offshore regulatory safety regimes, DNV GL 04/2015. Retrieved from: https://www.dnvgl.com/oilgas/regulatory-outlook/

DWH. (2011): Deepwater Horizon, 2011, National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011, Deep Water – The Gulf Oil Disaster and the Future of Offshore Drilling– Report to the President. ISBN: 978-0-16-087371-3.

DWH. (2016): Deepwater Horizon, 2016, U.S. Chemical Safety and Hazard Investigation Board, Investigation Report, Drilling Rig Explosion and Fire at The Macondo Well, Report No. 2010-10-I-Os 04/12/2016

Dekker, S. (2012). *Drift into failure. From hunting broken components to understanding complex systems*. Ashgate Publishing. ISBN: 978-1-4094-2223-5. Kindle Edition.

Gee, J. P., & Handford M. (2012). *The Routledge handbook of discourse analysis*. Routledge, ISBN 978-8-415-55107.

IOGP1. (2008). International Association of Oil and Gas Producers, 2008. Asset Integrity – The Key to Managing Major Incident Risks, Report No. 415.

IOGP2. (2011). International Association of Oil and Gas Producers, 2011. Process Safety – Recommended Practice on Key Performance Indicators, Report No. 456.

IOGP3. (2013). International Association of Oil and Gas Producers, 2013. Shaping Safety Culture through Safety Leadership, Report No. 452.

IOGP4. (2012). International Association of Oil and Gas Producers, 2012, Cognitive Issues Associated with Process Safety and Environmental Incidents, Report No. 460.

IOGP5. (2014). International Association of Oil and Gas Producers, 2014, Operating Management System Framework for controlling risk and delivering high performance in the oil and gas industry, Report No. 510.

IOGP6. (2016). International Association of Oil and Gas Producers, 2016, Standardisation of barrier definitions – Supplement to Report 415, Report No.544.

ISO. (2009a). Risk Management – Vocabulary. Guide 73:2009.

ISO. (2009b). Risk Management – Principles and guidelines. ISO 31000:2009.

Hollnagel, E. (2014). *Safety-I and Safety-II*. Ashgate. Kindle Edition.

Kahneman, D. (2011). *Thinking, fast and slow*. Farrar, Straus and Giroux. Kindle Edition.

Kay, J. (2011). *Obliquity: Why our goals are best achieved indirectly*. Profile Books. ISBN 978 1 84668 289 6, Kindle Edition.

Le Coze, J. C. (2013). New models for new times. An anti-dualist move. *Safety Science*, *59*, 200–218. Retrieved from: http://dx.doi.org/10.1016/j.ssci.2013.05.010

Le Coze, J.C., 2017, Globalisation and high-risk systems, Practice and Policy in Health and Safety, https://www.academia.edu/33792059/Globalisation_and_high-risk_systems?auto=download&campaign=weekly_digest

March, J. G. (1994). *Primer on decision making: How decisions happen*. New York, NY: Free Press. ISBN-13: 978-0-029-20035-3.

March J. G. (1999). *The pursuit of organizational intelligence*. Oxford: Blackwell Publishers Inc., ISBN 0-631-21101-2.

McKinsey. (2013). *Disruptive technologies: Advances that will transform life, business, and the global economy*. McKinsey & Company 2013, McKinsey Global Institute. Retrieved October 6, 2016 from: http://www.mckinsey.com/search?q=disruptive%20technologies%20report%202016

Meadows, D. (2013). *Thinking in systems: A primer*. Chelsea Green Publishing. Kindle Edition.

Mintzberg, H. (2013). *Simply managing: What managers do – And can do better (Financial Times Series)*. Pearson Education Limited. Kindle Edition. ISBN 978-1-292-00220-0 (ePub)

Morin, E. (2008). *On complexity*. New York, NY: Hampton Press, ISBN-13: 978-1572738010.

OECD. (2003). *Emerging systemic risks in the 21st century*. Paris, France: OECD Publications, ISBN 92-64-19947-0.

Page, S. E. & Miller, J.H. (2007). *Complex adaptive systems: An introduction to computational models of social life (Princeton Studies in Complexity)*. Princeton University Press. Kindle Edition.

Perrow, C. (2011). *Normal accidents: Living with high risk technologies*. Princeton University Press. Kindle Edition.

Power, M. (2007). *Organized uncertainty: Designing a world of risk management*. Kindle Edition.
Rasmussen, J. (1997). Risk management in a dynamic society: A modelling problem. *Safety Science*, *27*, 183–213. doi:10.1016/S0925-7535(97)00052-0
Snowden, D. (2011). Good fences make good neighbors. *Information Knowledge Systems Management*, 10, 135–150. doi: 10.3233/IKS-2012-0190, IOS Press
Snowden, D. J. (2005). Multi-ontology sense making: a new simplicity in decision making, 2005. *PHCSG, British Computer Society, Informatics in Primary Care*, *13*, 45–53. doi:10.14236/jhi.v13i1.578
Taleb, N.N. (2012). *Antifragile: Things that gain from disorder*. Penguin Books Ltd. Kindle Edition.
TC. (2007a). The BP U.S. Refineries Independent Safety Review Panel – January 2007.
TC. (2007b). U.S. Chemical Safety and Hazard Investigation Board, Investigation Report Refinery Explosion and Fire, Report No. 2005-04-I-Tx – March 2007
Turner, B. A. (1976). The Organizational and interorganizational development of disasters. *Administrative Science Quarterly*, *21*, 378–397 Source: Published by: Johnson Graduate School of Management, Cornell University Stable URL: http://www.jstor.org/stable/2391850 Accessed: 20/11/2009 04:57. doi:10.2307/2391850
Weick, K.E. & Sutcliffe, K.M. (2011). *Managing the unexpected: Resilient performance in an age of uncertainty*. Kindle ed. Wiley, ISBN: 978-0-7879-9649-9.
Weick, K.E. (2012). *Making sense of the organization, Volume 2: The impermanent organization*. Wiley. Kindle Edition. ISBN 978-0-470-74220-4 (pbk.)