Safety science: a situated science

An exploration through the lens of Safety Management Systems

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Abstract

A number of key concepts have punctuated the development of Safety science. Reflecting on what the next ones could be is a tricky exercise. How come certain safety concepts or theories or dispositive in the sense of Foucault emerge and become 'dominating concepts' or turning points in safety science? The paper considers a case from the past, namely that of Safety Management System (SMS), as a proxy to shed light on this question. The origins of SMS are explored to unravel what lies behind its emergence and development. The research is based on a literature review and open-ended interviews of 15 people who played a personal part in safety science or practices development before and/or when SMS started to emerge. Overall, the sample of interviewees represents a range of safety stakeholders (academia, industry, regulatory bodies, consulting companies) and high-risk industries to provide a diversity of perspectives on the emergence of SMS. The analysis of this material highlights several aspects that contributed to converge towards an approach like the SMS, beyond the identified limitations of safety science at that time. First, the intellectual context in which SMS emerged, was that of major developments on organizational and managerial dimensions of safety. Second, most safety stakeholders had motivations beyond safety enhancement to move towards a new approach. Last, the overall environment, way beyond safety and high-risk industries, facilitated the convergence towards an approach like the SMS. Eventually, this research demonstrates that safety is a situated science, situated not only in time, but also in a much wider economic, industrial, political, societal context. Putting safety into such perspective opens new avenues for reflecting about the future of safety science considering current trends not only in safety but also way beyond.

Keywords

Safety Science; Safety Management System (SMS); Societal context; Enabling context

Introduction

Reflecting about the future of safety science is a tricky exercise. Although one can have a performative approach to the description of a possible future, it partly denies the existence of uncertainties, at least the temporal uncertainty (Rowe, 1993). In the case of safety science, the diversity of views and developments adds on to the challenge intrinsically related to that of anticipation, when it comes to reflecting about its future. Indeed, without entering the debates around the scientific validity of safety science, largely addressed in the special issue of *Safety Science* of August 2014 and in the "founding fathers' retrospection" (Stoop et al., 2017), safety science cannot be considered a unified science where there is an overall or even some kind of wide consensus on concepts, theories, models or tools (Ge et al., 2019).

From a historical perspective, several major turning points triggering new eras of safety science development were identified. Dekker (2019), for example, highlights eleven turning points since the beginning of the last century, each characterized by a dominating trend or concept. Just to mention the past three decades, the author identifies, "Swiss cheese" and "safety management" as dominating concepts in the 1990s, "safety culture" in the 2000s and "resilience engineering" in the 2010s. However, even if new ideas, approaches or theories were indeed advanced at some point in time, in practice, research is still ongoing on most of the founding concepts and theories that emerged decades ago, such as High Reliability Organization that appeared in the late 1980s or "system safety" in the 1950s/60s. A variety of safety science schools of thought and practices keep existing and developing in parallel. In addition, depending on the industry, and /or the applicable regulatory requirements and regimes, different directions are explored to enhance safety before some of them become widely adopted with time and recognized as generic safety science developments.

A number of needs and challenges are identified today by safety scientists or practitioners, in relation to either the evolution of high-risk activities or the intrinsic characteristics of safety science (Le Coze, 2019a). For example, complexity is currently identified as insufficiently addressed by safety science be it that of technology, organizations or institutions for example (Stoop et al., 2017; Le Coze, 2019b; Schulman, 2020). In relation to complexity as well, but primarily operational complexity and its contingencies, another major challenge widely acknowledged is how to cope with the unexpected or being "prepared" to be unprepared (La Porte, 2020; Weick & Sutcliffe, 2016; Grote, 2015). With the increase of security threats and the demonstrated coupling of safety and security, this question becomes an even more burning issue and opens as well to a number of possible future developments (Bieder & Pettersen, 2020). On the technological side, digitalization and the development of artificial intelligence is another area that poses new safety questions and issues (Almklov & Antonsen, 2019).

Beyond the evolution of high-risk activities and the way they are performed, challenges intrinsic to the current state of safety science are also pointed out by some authors. Schulman for example, underlines the need to be more constructive and collectively cumulative as safety scientists (Schulman, 2020). The challenges of getting different disciplines to collaborate with one another in a highly transdisciplinary domain such as safety was also discussed by Le Coze (2019b).

This landscape of possible avenues to explore identified within the safety science community may provide interesting insights as to future areas of research, but is it sufficient to anticipate possible future major steps in safety science? How come certain safety concepts or theories or dispositive in the sense of Foucault emerge and become 'dominating concepts' or turning points in safety science as named by Dekker (2019)? Very little knowledge is available regarding this genesis and spreading of new safety approaches. Yet, understanding why and how a new idea emerges at a certain point in time and develops, to a point where it starts spreading widely, could help reflecting about the future of safety science.

The work presented in this paper focuses on the emergence of one safety approach characterized as a turning point by Dekker (2019), namely, Safety Management Systems (SMSs). SMS can be used as a proxy for a broader reflection on safety science because: a/ it is commonly used in many high-risk industries today (it is even often a regulatory requirement in highly regulated activities) and is still considered a promising way forward safety wise. As an example, following the preliminary report on the investigation of the two Boeing 737 MAX, the Federal Aviation Administration recommended to reinforce the SMS for aircraft manufacturers[1]. In that respect, the SMS provides some insights about the safety science situation today even though safety science includes many other safety concepts, theories and approaches, some of which are commonly used as well today, often in parallel with the SMS when the latter is implemented; b/ it is an example 'sufficiently' from the past to have reached the status of a 'dominating concept' in safety science considering the numerous traces of its reach and penetration in many areas, especially the industry, regulation or academia. As such, it can support a reflection about the future of safety science and the possible 'dominating concepts' or turning points to come. At the same time, the advent of the SMS is 'recent enough' to allow for a comprehensive investigation of its origins, including through the views of those who contributed to or witnessed its genesis.

A Safety Management System is an approach to systematically manage safety. Although detailed characteristics may vary from one high-risk domain to another, overall, all SMSs share the following features (already present in Kysor's papers in 1973): a/a definition of the organizational structure that needs to be put in place to manage safety, including objectives, policies and accountabilities; b/

[1] https://www.reuters.com/article/boeing-737max/faa-to-mandate-new-safety-management-tools-for-airplane-manufacturers-idUSL1N2D11CX

analysis of operational risks; c/ a definition of a safety assurance process (including the definition and implementation of risk control measures) to keep the risks at an acceptable level; d/ a risk communication process.

This paper aims to add knowledge to the emergence of new safety approaches by investigating that of Safety Management Systems (SMSs), first discussed in the 1970s and progressively adopted as a new safety frontier in the 80s and 90s. In particular, the research sheds light on what motivated a change of safety approach at that time, as well as what contributed to the convergence towards an approach like the SMS. The results are then discussed in the light of today's context to draw some lines of reflection about the future of safety science reaching beyond its current identified limitations and needs.

Literature review

The history of safety science has been largely explored in the literature ((Swuste et al., 2016, 2018; Dekker, 2019; Le Coze, 2019a). Different time frames and steps or turning points have been considered with small variations from one author to the other. However, very little is explored regarding how the new concepts, theories or dispositives appeared. Bourrier (2011) provides insights on the genesis of the High-Reliability Organization theory through an ethnographic approach. The author explores several dimensions: the founding fathers' and mother's profiles, the group's ways of working and the intellectual context at that time (especially the paradox faced by the group when comparing its field observations with what the recently published Normal Accident Theory (Perrow, 1984) would lead to expect). Nevertheless, such endeavors to understand what contributes to the emergence of a new vision are extremely rare. SMS is no exception to that. Although the number of publications on SMS has been growing dramatically over the past decades[2], most of them focus on the definition of SMS, its characteristics, its implementation in a variety of domains, its evaluation. Nevertheless, some insights are provided by Li and Guldemund (2019) from their extensive literature review on the commencement of SMSs. They characterize the latter as the merging between an insurance approach focused on risk management and an industrial approach focused on accident prevention and the development of safety defenses. However, very little is said about what contributed to this merging. The main argument advanced is the improvement of technology inducing more complicated safety defences, thus requiring management systems to "implement, maintain and update these" (Li and Guldemund, 2019, p.97).

[2] From 3 papers in the 1970s, the number went up to 228 in the 1990s and kept increasing exponentially with a total number close to 3000 publications as of mid-2019 (Source: Scopus using the keyword "Safety Management System").

More generally, the emergence of new concepts, theories or approaches is not a widely explored area in safety science. From a broader perspective, Kuhn (1962) in his essay on the structure of scientific revolution identifies as a driver for new paradigms the existence of anomalies or violation of expectations, that is, facts that cannot be explained using existing theories or concepts. However, besides the limitations of existing scientific developments as drivers for new paradigms, Kuhn also acknowledges that the "conditions outside the sciences may influence the range of alternatives available to the man who seeks to end a crisis by proposing one or another revolutionary reform » (Kuhn, 1962, p. x). One important aspect in these outside conditions is the world of ideas available to the scientists. According to the author, shifts in visions do not result exclusively from the genius of individuals, be them called Aristotle or Galileo, but also from the world in which they were immersed, especially, the intellectual environment and the knowledge available at the time. Without being as far reaching as scientific revolutions, Jasanoff (2004) highlights that science is intertwined with societal evolution. "Science and society are *co-produced,* each underwriting the other's existence" (Jasanoff, 2004, p.17). Therefore, exploring the societal context makes sense to understand the genesis of scientific developments.

Closer to safety, other authors have pointed out the influence of the context on the development of safety vision and approaches. Merritt & Maurino (2004) illustrate the role of cultural aspects but also that of the resources available to perform research, not only the financial or technological ones, but also the ongoing access to news ideas and theories (p. 176). The influence of the political context is also emphasized, especially in relation to the emergence of the safety culture concept following the Chernobyl accident (Dekker, 2019). More recently, when reflecting about the future of safety science, Dekker (2020) makes a link between recent safety developments and neoliberalism, highlighting the impact of the overall political, economic and social context on safety and its evolution. In short, it seems that scientific developments may be influenced by a broader context that reaches beyond the identified limitations and needs of the science itself.

Methods

To try and understand the origins and generalization of safety management systems (SMS), a research was conducted based on a literature review and interviews of stakeholders who participated in the emergence and spreading of SMS. As underlined by Descamps (2005), interviews allow for reaching beyond the official, declared objectives and strategies of organizations. Besides, although written sources present a rather linear and rational story, interviews give access to "the complex interactions between the structure, the strategy, the actors and external environment permanently changing" (Chandler, 1989, cited by Descamps, 2005, pp.578-579).

In total, 17 persons were interviewed between July 2018 and July 2019. They were chosen for the personal part they played in safety science or practices development before and/or when SMS started to emerge either in their own domain or more globally. Overall, the sample of interviewees represents a range of safety management stakeholders, high-risk industries and countries to provide a diversity of perspectives on the emergence of SMS. 4 interviewees were from regulatory bodies, 3 from high-risk industrial companies, 3 from academia, 2 from consulting companies on safety management and 3 had hybrid profiles including two or more of these experiences either sequentially or simultaneously. The interviewees came from 7 different countries from Europe and

America. 7 out of the 15 were already involved in safety in the 70s, 6 started in the 80s, and 2 in the early 90s.

The interviews were open-ended interviews, lasting between one and three hours. They were conducted in English for non-native French speakers and in French for the others. The interviews were not recorded but extensive notes were made in real-time and were afterwards validated by the interviewee.

A qualitative content analysis method was used to process the interview data since this historical investigation didn't rely on *a priori* assumptions or theory (Descamps, 2005). Considering the limited size of the sample, the analysis was still manageable without software assistance and was performed manually. The analysis of these data led to characterize: a/ the intellectual context and background in relation to safety when the idea of SMS started to appear; b/ the actors who played a part as well as their motivations to move towards a new safety approach; c/ key aspects of the overall context that facilitated the convergence towards an approach like the SMS.

Results

The intellectual context and background related to safety around the 70s

The SMS is not a revolutionary concept or dispositive that spontaneously appeared. Its emergence is closely linked to the evolution of safety thinking. A number of ideas and practices in relation to safety already existed in the 70s and even earlier, and the intellectual context was dynamic with number of developments to better understand and address safety. Some of these developments were led by the industry, insurance or consultancy business, others were more scientific, led by academics. However, the boundaries are not always easy to draw for some key actors had a multi-fold activity.

The first publication mentioned in Scopus in relation to Safety Management System dates back from 1973 and appears in the *National Safety News*, a US National Safety Council publication. H.D. Kysor, the author, is not an academic with a safety related background but rather an aeronautical consultant. In his two papers on SMS, *Part I: the design of a system* (Kysor, 1973a), and Part II: *SMS organization* (Kysor, 1973b) one can find most of the ideas that can be found today in SMS requirements.

Within industry, the idea of safety management was introduced in the 1920s by Louis De Blois, safety manager of Dupont, according to a kind of risk concept that he invented, based on the two principles that "hazard is energy and management is responsible" (Academic 2, diverse industries, June 14, 2019).

Coming from a different perspective, that of insurance, the contribution to accidents of workers' social environment (underlying human unsafe acts) was identified in the industry as early as in the

30s by Herbert Heinrich in the US. The analysis of the root causes of thousands of accidents (workplace accidents) in the steel industry led him to develop the dominos' model and to derive recommendations in terms of managerial practices. In the 70s, in the US as well, Frank Bird Jr., further developed and refined Heinrich's dominos' model, especially through the description of managerial factors likely to lead to a human unsafe act (Bird, 1974). He then turned this model into an audit tool to help managers self-check they were doing what was needed (or described to be needed) to prevent accidents and associated losses. This audit model, called the International Safety Rating System (ISRS), consisted of a practical tool, namely a series of questions that managers could use to check whether they were covering all the aspects of management contributing to safety (or modeled as such). According to one of the interviewees, "the ISRS had no scientific foundations. It was just the codification of industrial practice" (Academic 1, diverse industries, September 11 & 20, 2018). Yet, its development was derived from the incident causation model he developed based on the analysis of more than 1.7 million accident reports.

On the academic side, the interest in safety developed in the 70s and 80s to a point where dedicated multi-disciplinary research departments and specific courses were set up for example at Delft University in 1978 (Stoop et al., 2017). Along the same lines, the journal *Safety Science* was first issued in 1976. Although safety approaches had so far mainly focused on technology and human factors (understood essentially as first line operators' errors), Barry Turner, a sociologist, published in 1978 *Man-made disasters*, a book theorizing the organizational vulnerability to accidents. In his book, Turner (1978) highlighted the existence of a long period of incubation before the occurrence of an accident, during which the organization remains blind to all signs contradicting existing beliefs and norms. This was the first account of an organizational contribution to accidents.

Motivations for a new approach

Although enhancing safety is an obvious reason to improve the way safety is managed, other aspects and motivations come into play in the emergence of an approach like the SMS. This section explores the motivations, including beyond safety itself, of the main safety management stakeholders for moving towards a new approach.

Academics: the limitations of an individual focus

Among the main drivers for scientific developments in safety science at that time was a series of accidents (e.g. Flixborough in 1974, Bhopal in 1984, Challenger in 1986, Chernobyl in 1986). Indeed, the dominant accident models and safety thinking of that time, focused on technical and human factors aspects, couldn't provide sound explanations of these disasters. The research environment on safety evolved and can be characterized by several waves of developments emphasizing the role played by organizations on safety. Several organizational angles were proposed to describe and explain either accidents, or alternatively, how safety can be ensured. Social scientists adopting a more qualitative and 'situated' approach based on field research work started to pay more attention to organizations as contributors to safety or to accidents (La Porte, 1994; Vaughan, 1997; Perrow, 1984; Reason, 1990). Two distinct academic profiles can be identified, with different contributions: psychologists such as Andrew Hale, Bernhard Wilpert or James Reason, extending their scope from individual behaviors to organizations following major accidents becoming hard to explain on the sole basis of individual behaviors; sociologists or political scientists, with two types of contributions. First, the analysis of how high-risk organizations drifted and/or failed (Turner was a pioneer in this area). For example, organizational mechanisms whereby deviance become normalized were described by Diane Vaughan in 1996. Second, an analysis of how high-risk organizations successfully managed to sustain a high-reliability performance like for example La Porte, Schulman and the whole Berkeley school of thought on HROs in the late 80s, proposing the High-Reliability Organizations theory (La Porte, 1996). The introduction of a more managerial-like approach in academic research, emphasizing the key role played by management in ensuring working conditions preventing unsafe acts can be associated with the development of the Swiss Cheese model by James Reason in the late 80s, and published his book on Human Error (Reason, 1990).

Insurance companies: better calibrating premiums

Beyond any ethical consideration, one of the stakes, especially for insurance companies, was the cost of accidents. Therefore, safety management became a wider concern in the 70s for these companies, especially in the US. Indeed, the main challenge was to calculate insurance premiums depending on what industrials had in place to 'manage' safety in a societal context where companies needed to subscribe a private insurance for there was no public insurance system in some states in the US at that time. In such context, the insights drawn by Frank Bird Jr., originally an engineer and then a safety manager in the steel industry in the US, led an insurance company to recruit him in 1968. "What he had developed served as a structure to determine the level of risk of a company, thus its insurance premium. Frank Bird tried to put criteria to determine this premium" (Consultant/industry 2, diverse industries, 21 December 2018).

Industrials: trauma, ethics and performance

On the industrial side, historically, part of the motivation for Dupont to enhance safety management in the 1920s was the fact that "the factory of [the company] blew up regularly" (Academic 2, diverse industries, June 14, 2019). Accidents were still part of the factors that led companies, essentially in the mining, oil & gas, chemical, food processing industries to turn to Franck Bird Jr's consulting company in the 80s and 90s. As mentioned by one of the former employees of this company:

"Their [the companies we were working for] initial motivation was often triggered by a trauma, either internal or close to the company or experienced by one of the organization's leader in his previous company. The change to adopt the ISRS[3] was not spontaneous, it was rather an electroshock" (Consultant/industry 2, diverse industries, December 21, 2018).

However, other motivations were mentioned by the interviewees regarding the decision to develop or adopt different approaches to further enhance safety in the 90s, including ethical reasons, beyond the reduction of the costs associated with accidents.

As stated by one of the interviewees: "Management systems were already discussed at that time internally. Chemistry was a leader in terms of safety and safety management. HSE[4] as well as social aspects were explicitly part of the values promoted by the company. It was agreed at the top level of the company that people were working at [name of the company] to make a living, not to lose their lives. It wasn't just words." (Industrial 2, chemistry, January 25, 2019)

In the 90s, other industries in different countries as well funded their own research and development to further enhance their approaches to manage safety. It was the case of Shell in the oil & gas industry wanting to develop their own methods to identify organizational contributors to safety and performance more generally. Enhancing safety management was seen as a way to improve their overall performance by some companies' and formed part of their motivations to move towards a new approach. In the case of the adoption of the ISRS, "safety was just a pretext. It consisted in expecting from each manager to bring its contribution to the good functioning of the company and to take his share of responsibility" (Consultant/industry 2, diverse industries, December 21, 2018).

In the nuclear industry where the main approach to safety was certification, EDF in France, as well as the NRC (Nuclear Regulatory Commission) in the US, developed new HRA (Human Reliability Analysis) methods to integrate 'on-line' safety management aspects and operating experience. Performing these more sophisticated analyses would not only respond to the mandatory certification requirements, but also, beyond the certification exercise, allow drawing useful insights to enhance safety (Bieder et al., 1998; Cooper et al., 1996). In France, the trigger was a change in technology with the introduction of computerized control rooms and the need to certify these new N4 reactor types with these novel control rooms. These HRA developments were focused on enhancing safety by design of a socio-technical system rather than by supporting managers in addressing safety.

Regulators: overcoming the pitfalls of command and control

Different motivations were also identified on the part of regulatory agencies, not all similar nor synchronized in time. Coming from different regulatory regimes, several countries played an

[3] The ISRS (International Safety Rating System) was a tool to support managers in managing safety developed by F. Bird Jr. and sold to industrials when he decided to set up his own consulting company after him years spent in an insurance company.

[4] Health Safety & Environment

influential role in the development of a new approach to safety management, such as Norway (especially the oil & gas industry there), the Netherlands or the UK.

The reconsideration of the ’command and control‘ model of regulation is dated back to the end of the 60s. It translated into some influential reports such as the Robens Committee one in the UK published in 1972 and criticizing the traditional regulation model, mainly a top-down one, or the introduction of the “humanization of work” concept in the Netherlands inspired from the Norwegian Work Environment Act published in 1977 (Aalders & Wilthagen, 1997).

The Norwegian Petroleum Directorate (NPD), established in the 70s to regulate and oversee the emerging oil & gas activity, soon initiated reflections on the regulatory regime to be adopted in their particular context where (Lindøe and Olsen, 2009):

- the Norwegian Work Environment Act of 1977, “the world’s possibly most stringent labour legislation” (*ibid*, p.432) was in place;
- the offshore industry was densely unionized “with extensive collective bargaining rights and a comprehensive network of safety representatives” (*ibid*, p.432);
- two major accidents occurred (the blow-out on the ‘Bravo’ platform in 1977, the capsizing of the ‘Alexander Kielland’ platform in 1980) showing the limitations of the regulatory regime in place.

The NPD pushed for moving from a reward and punishment to a mutual understanding and cooperation approach to safety regulation (Lindøe and Olsen, 2009; Hovden, 2002; Hovden & Tinmannsvik, 1990).

This reflection initially gave rise to an Internal Control approach that was then extended to all industries to overcome a double bind resources issue. The first issue is a qualitative one related to the increase in complexity and automation in industry, making it hard for a regulatory agency to keep up with. The second issue is a quantitative one since resources were becoming too limited to continue traditional monitoring (Hovden & Tinmannsvik, 1990).

In the UK, beyond the Robens report, the motivation for regulators to change approaches (initially in process industry) also came from doubts expressed by the civil society about the efficiency of regulators with a series of accidents occurring in the 70s and 80s, but more generally about public services as further detailed in the following section. In this context, beyond the enhancement of safety, regulators had two major challenges, namely, protect their liability and demonstrate their efficacy (Power, 2004). In rail, a similar need to change approaches was identified in the 90s following a decade of mediatized accidents. “There were also a lot of rail accidents, or the media were more focused on accidents whereas they were silent in the past”. (Academic 2, diverse industries, June 14, 2019). “There was a decision made by the secretary of state not to put a warning system on trains before this series of accidents. They had made a quick calculation on the back on the envelope and came to the conclusion that it was not worth it. The “Yellow book” which was their basis to perform risk assessment in the 90s had led to calculations ‘proving’ that it was safe enough as such. But then this series of accidents happened. This risk assessment approach based on calculations was not working so well in rail” (Mixed experience 1, diverse industries, January 21, 2019).

In aviation in Europe, regulation was essentially based on certification. The need for moving towards new approaches came even later, just before the turn of the 21st century, with the corporatization of Air Navigation Service Providers in some countries like the UK for example in 1996. “The privatization or corporatization of public services was a strong incentive to rule the economic and safety aspects independently from one another. Economic aspect to make sure that the increase of profits wouldn’t be done to the detriment of clients. Safety aspect to make sure that safety wouldn’t be sacrificed to the benefit of other business indicators” (Regulator 3, aviation, February 20, 2019). Regarding how to rule the safety aspects, the main push came from the UK. “The UK CAA Safety Regulation Group had a vision of how the regulator should intervene, considering that they had an issue to remain competent on technology and that they didn’t want to take the responsibility of a detailed prescriptive and oversight approach. They were willing to focus the approval on the safety management system rather than on operational aspects. They had had bad experiences.” (Regulator 4, aviation, February 25, 2019) “The UK was perceived as dominant. The chairman of the SRC[5] came from the UK. The head of the SRU[6] came from the UK. The other countries didn’t have the experience. They were not doing such thing in their countries.” Aviation relied on the railway experience in the UK that went through the privatization experience earlier which led to learn the hard way. “How this interface would work didn’t come from aviation in the UK. It came from the experience in the railway industry after it was privatized in a context of a liberal political system and more generally a certain vision of the world. The UK experienced a number of rail accidents which led to the clarification of control functions, especially for safety” (Regulator 4, aviation, February 25, 2019). However, despite the early developments of safety management, the real push towards a change in regulatory approach happened following the Milan Linate and Überlingen accidents, respectively in 2001 and 2002, revealing that there were “organizational and oversight shortcomings.” (Industrial 3, aviation, February 12, 2019).

Civil society: a growing suspicion

An interesting angle to understand the societal push towards a new approach to safety management is provided by the ‘risk society’ theoretical perspective developed and addressed by Giddens (1990) and Beck (1992). In this perspective, risk is seen as amplified by the post-modern era where risks are spreading and amplifying due to industrialization, globalization and urbanization, created and accelerated by human activities.

In the 80s, as described by Beck (1992), the consciousness of self-produced or manufactured risks was increasing, creating enhanced public anxieties fueled by media. Likewise, the public defiance towards the governmental institutions and experts’ opaqueness was growing at that time (Giddens, 1990; Beck, 1992; Hutter, 1997; Power, 2004). Indeed, the public started to realize that experts were disagreeing and that governments were failing to act, not to mention a certain suspicion towards science that also contributed to modernization, thus to the development of risks. Both the public and the media were less willing to accept advice from experts or to rely on regulatory models that they

[5] Safety Regulation Commission
[6] Safety Regulation Unit

suspected were lacking knowledge about a growing number of risks. The public expected decisions and demanded the right for considering decision-makers accountable (Power, 2004, p.14).

An enabling overall context

If most safety stakeholders had diverse motivations to move towards new safety management approaches, it is worth wondering why Safety Management Systems turned out to be “the” most relevant approach crystalizing the variety of interests at stake. Exploring the overall context beyond safety itself in the late 70s and 80s when SMS started to largely emerge and be adopted provides some insights.

An injunction for transparent and efficient control

A big wave of deregulation occurred in the 80s, driven by a concern with over-regulation of business and uncontrolled costs of regulation which still left serious doubts about the efficiency of the regulatory practices in place. The 70s and 80s were indeed decades of a number of major accidents such as Flixborough (1974), Piper Alpha (1988), Herald of Free Enterprise (1987). The concern with regulation and its efficiency was in fact much broader than safety. It led in the 80s to the advent of the New Public Management in the UK.

The growing public injunction for transparency, control and accountability of public services was identified as a driving force for the explosion of audits in the UK in the 80s, combined with the evolution of the regulatory strategy towards a ‘control of control’ or oversight of internal control strategy, not only in the domain of safety (Power, 2000). More generally, the move towards the ‘risk management of everything’ is a way to define a structure of (apparent) control and accountability that provides the reassurance called for by the public including regarding the governance of the unknown (Power, 2004).

As characterized by Hood (1995), “the basis of NPM[7] lay in reversing the two cardinal doctrines of PPA[8]; that is, lessening or removing differences between the public and the private sector and shifting the emphasis from process accountability towards a greater element of accountability in terms of results.” (p.94). Progressively, the NPM model spread across the OECD[9] countries even though there were some variations in the way and pace at which the model was implemented (Hood, 1995). A similar wave was observed in other European countries and the US starting in the 80s, emphasizing the cost issue (Hutter, 1997). Regulators were forced to legitimate their own activities by demonstrating they were operating both efficiently and effectively, that is without wasting resources and by proving that their activities were making a difference. They adopted a private sector style of management and risk-based approaches allowing for benchmarking public sector

[7] New Public Management
[8] Progressive Public Administration
[9] Organization for Economic Cooperation and Development

activities against private sector activities. These approaches not only incorporated a cost-benefit approach, but they also had the apparent benefit of being 'objective' and transparent and perceived as efficient to support resources allocation, tested and trusted by the business community (Hutter, 1997).

However, this apparent transparency reaches beyond the sole objective of legitimating regulators activities. It also constitutes an alibi, a 'demonstration' that everything was done to prevent failure. As such, it is a form of preventive accountability to avoid being blamed in case of failure (Power, 2007).

This societal context in the 80s/90s is not just valid in the UK as a consequence of 'Thatcherism', but is rather related to the "organization of trust in modern societies and institutionalization of checking mechanisms". (Power, (the audit society preface to the paperback edition in 1999, p. xvi)).

In this context, the generalization of internal control leads to a new balance between resources and responsibility, more specifically to an evolution from detailed prescriptive laws and regulations specifying the preventative measures to be implemented to more formal and calculative approaches, that can be audited based on a generic structure to make them reasonably one-size-fits-all tools for assessing a wide range of companies (Hale, 2003). The arguments put forward to support this move were a combination of a systematic and verifiable way to work with safety, a management system for safety, some leeway for each company to find their own solutions to safety & work environment, a way to place responsibility to individuals, including managers and directors, and also a way for fostering a dynamic approach and up-to-date solutions to safety problems (Hovden & Tinmannsvik, 1990). By making internal control or self-regulation a regulatory requirement, authorities foster the generalization and further development by companies of internal control in a kind of ultimately self-reinforcing mechanism (Power, 2007).

The Quality Management wave

Although "TQM's origins can be traced to 1949, when the Union of Japanese Scientists and Engineers formed a committee of scholars, engineers, and government officials devoted to improving Japanese productivity, and enhancing their post-war quality of life" (Powell, 1995, p.16), it was introduced in the US in the 70s (when Japanese products penetrate the US market and as well as a result of the impact of Deming, Juran and other authors' writing) and in the UK in the early 80s with the objective to enhance product quality, hence ultimately productivity (Martinez-Lorente et al., 1998). This quality management wave translated into the publication of the ISO 9000 norm in 1987 and the voluntary compliance with this standard having no authoritative power reflecting the evolution of the whole society towards increased bureaucratization and blurred boundaries between 'public' and 'private' (Hibou, 2012). Quality

Management Systems started to be part of the organizational landscape. Although ISO standards initially focused on quality, groups were set up in the 80s and 90s to extend the quality management approach to environment and then safety.

The development of standards (under the lobbying of certification companies) led to a shift of focus and understanding by some high-risk companies that saw in the standards not the minimum but what needs to be done (i.e. something like the maximum), an external recognition or sign of safety consciousness and a cheaper option than other in-depth analysis approaches. Therefore, a number of industries that had adopted the ISRS initially developed at a time where there were no ISO norms, mistook it for a management system and welcomed more standardized approaches. "Some companies came to the ISRS although all they wanted was the score. They would get the scores but not the actual outcome (…) The ISRS was also a matter of external acknowledgement/recognition. Companies would display their certificate in a visible location on the wall. Getting an ISO certificate was easier" (Consultant/industry 2, diverse industries, December 20, 2018).

This standardization was also a good opportunity for certification companies and emerging consulting companies making of the compliance with standards a juicy business and cutting costs paving the way to a "low cost safety management" (Almklov, 2018).

A practical approach endorsed by safety science after the fact

The role of management and organizations in safety was analyzed and highlighted within the safety science community leading to a number of theories as described earlier. The academic topic of research was safety management. Interestingly, the theories coming from social scientists were descriptive and didn't rely on a hierarchical control model, thereby failed to meet industrials' expectations. As stated by one of the industrial interviewees: "The ISRS was attractive for [name of the company] people for they had a scientific background and wanted a framed approach. There was a control loop (each item was graded: operational, need to improve or non-operational) and it was prescriptive" (Industrial 2, chemistry, 25 January 2019). Eventually, the SMS, as it emerged as a way to account for the role of management in safety, doesn't originate from scientific developments. The SMS developed despite the absence of scientific evidence (Hovden & Tinnmansvik, 1990) significantly driven by forces outside the safety science arena and was then tentatively addressed in this arena. Put in one of the Academic interviewees' words, "when SMS became an item, Academics wondered how to do that" (Academic 2, diverse industries, June 14, 2019). Turning to SMS for academics was a way to push scientific ideas on the role of management on safety but also a way to get funding. "The industrials would listen to academic SMS people who moved where the money was" (Academic 1, diverse industries, 11 & 20 September 2018).

Discussion

Although the SMS is considered a turning point in safety science (Dekker, 2019), its emergence reflects and crystalizes the needs, trends and expectations of a global industrial, economic, political and societal context, far beyond the thinking on safety of the 70s and 80s. The research reported here highlights the plurality of dimensions that come into play in the motivations of the different safety stakeholders to move towards a new approach. The main drivers are of very different natures. They include more specifically: technological progress and its related effects such as the challenges to keep up to speed with the pace of it, especially for regulators; the limitations of existing safety concepts and theories to explain real events; the concern of industrials to improve their overall performance in an increasingly competitive context. Besides these aspects calling for a new safety management approach, the overall context fostered the convergence towards an approach based on risk management and control. More specifically, among the key shaping factors were: the generalization of total quality and quality management systems (originally to improve companies' performance) ; the societal crisis of trust in public institutions and experts, but also in technology for they increased the will to manage and control everything both internally and externally, using private companies' approaches and tools (Power, 2004).

Of course, the research presented in this paper is limited to the genesis of the SMS, that is of one safety 'dominating concept' in the history of safety science. The results would need to be complemented through the investigation of other examples to come up with a more consolidated framework to think and understand the emergence of safety science 'turning points'. Nevertheless, the research outcomes lead to consider safety as a situated science; situated not only in time with a certain state of knowledge and technology, but also in a broad multi-dimensional context, characterized by certain world views, attitudes towards uncertainty, visions of trust and modes of interactions. The results unravel especially the influence of societal expectations and pressures with respect to technology and institutions as well as of industrial practices on the shaping of a widely accepted solution. This broad framework of the development of safety science 'dominating concept' invites to contemplate some of today's major trends that could constitute some of the conditions enabling the emergence of future safety science turning points.

Technology naturally comes to mind with the increased digitalization and development of technologies such as artificial intelligence and machine learning that pave the way for new 'operators' with unprecedented and evolving capabilities and new forms of 'autonomy'. Autonomous vehicles, drones, robots are already starting to raise a number of safety issues including in relation to regulation and governance (Macrae, 2019; Andrews, 2017). However, the impact of digitalization reaches far beyond safety itself, transforming social interactions, the foundation of trust or even making new sources of data (if not information) available and new processing possible, with a variety of effects in many domains.

Another current trend could contribute to shaping the future of safety science is the observed evolution of governance mechanisms whereby the civil society at different levels pushes to make behaviors evolve whether or not it involves institutional reactions. These phenomena, of which 'flight shaming' is an illustration, challenge still widespread models considering that government is the only actor managing and organizing societal and political solutions. More generally, "the shift to governance is best understood as response to new challenges, such as globalization, increased international cooperation (such as the European Union), societal changes, including the increased engagement of citizens and the rise of non-governmental organizations (NGOs), changing role of the private sector, an augmenting complexity of policy issues, and the resulting difficulty in taking decisions with confidence and legitimacy" (Renn et al., 2011, p.233), citing (Walls et al., 2005). Matyjasik & Guenoun (2019) explicitly envisage the end of the New Public Management[10] and the possible emergence of new modes of governance, some of which build by the way on the new capabilities offered by digitalization. The evolution of governance models at a global level may significantly impact safety and drive for new safety science concepts. Indeed, as shown earlier, the NPM played a key role in the emergence of an approach like the SMS, by calling for more transparency, control and responsibility.

Climate change, and the generalization of public acknowledgement of the urgency to address it, is another current trend to consider. Indeed, it may challenge the value of safety. It raises questions as to the relationship between safety and climate change. For example, will they be considered mutually reinforcing each other or competing with one another (and under what conditions) like safety and productivity have been for a long time and still are in many organizations? Other growing concerns raise similar questions as to their coupling with safety. It is the case of security for example (Bieder and Pettersen, 2020) or more recently with the Covid-19 outbreak of health.

Many recent disasters include a large number of natural disasters or attacks (cyber or physical) or more recently pandemics. Concerns like climate change, security or global health also induce a societal evolution that may shape future safety science concepts, namely, the attitude towards uncertainty. Whereas the society of the late 20th century was that of the risk control of everything (Power, 2004), a number of mediatized events challenge this view and reveals the limitations of risk control. It is the case of some extreme climate events like wildfires in California or Australia, or security events like 9/11, the Paris attacks in 2015 or the Germanwings accident, or more recently of the Covid-19 outbreak. These evidences that total risk control is an illusion call for the need to develop strategies to live with uncertainty more than try and pretend to reduce it totally.

[10] One of the enablers of the convergence towards the SMS.

Conclusions

The analysis of the genesis of SMSs, one of the 'turning points' in the history of safety science, provides some insights as to the many aspects that contributed to the emergence of such a 'dominating concept'. It reveals the multiplicity of motivations of the various stakeholders to change safety approaches, including beyond the enhancement of safety itself. Resource issues, global performance improvement or liability for example are dimensions that were part of the motivations. However, the convergence towards an approach inspired from industrial practices, based on the clarification of responsibilities and risk management also results from an overall enabling context. Indeed, the generalization of quality management systems and the development and spreading of New Public Management contributed to shaping a safety management approach that would be not only acceptable to all safety stakeholders, but also matching the political, economic and societal environment of that time. As such, the SMS as a new safety science dominating concept is situated. Although the detailed framework to understand the genesis of new safety science concepts would need to be consolidated, the research invites to contemplate safety as a situated science. As such, it opens new avenues for reflecting about the future of safety science considering today's world. It leads to putting safety into a wider context and perspective, considering some current technological and societal trends such as the generalization of digitalization, or the growing concerns about climate change, or the increasing acknowledgement of uncertainties and the need to live with them calling for other modes of governance. It also and maybe above all encourages to remain humble as to what can be advanced about the future of safety science.

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